JOHNSTON'S MODERN PRACTICE IN FIXED PROSTHODONTICS

DYKEMA GOODACRE PHILLIPS

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Fourth Edition

ROLAND W. DYKEMA, D.D.S., M.S.D., F.A.C.D.
Professor of Fixed and Removable Partial Prosthodontics

CHARLES J. GOODACRE, D.D.S., M.S.D.
Associate Professor of Fixed and Removable Partial Prosthodontics

RALPH W. PHILLIPS, M.S., D.Sc., F.A.C.D.
Associate Dean for Research and Research Professor of Dental Materials

Indiana University School of Dentistry, Indianapolis, Indiana

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This Book Is Dedicated To Our Wives

Dorothy Dykema

Ruth Goodacre

Dorothy Phillips

Without their constant encouragement and understanding
this project would not have been possible.

PREFACE

Extensive revision of this text has been necessitated by the time which has lapsed since the last edition and by the introduction of new materials and techniques. However, the authors believe that the conservative philosophy and promotion of excellence so eagerly and forcefully espoused by Dr. John F. Johnston are still properly addressed in this textbook.

In many chapters, more than one technique for accomplishing a task is given, with favored techniques being identified when indicated. The authors believe that a knowledge and understanding of alternative procedures allows one to manage clinical situations from more than one perspective, and that this stimulates both professional growth and the pursuit of excellence. It allows for continual evaluation of the adequacy of existing techniques and permits modifications to be made when innovations are developed that comply with the fundamental principles of fixed prosthodontics.

The goals of the first edition, as written by Dr. Johnston in the preface to the 1960 edition, seem most appropriate today and convey the objectives that the authors have attempted to meet in developing the text. "Its purpose is to be comprehensive but not encyclopedic in scope and to present basic knowledge and accepted techniques in a manner which will enable the student, or practitioner, to assimilate and apply them clinically. The clinical operations set forth are intentionally conservative so that the student will follow a plan designed to help avoid difficulties. The experienced clinician will broaden the application of many principles with complete success, at the same time observing the fundamentals."

ROLAND W. DYKEMA
CHARLES J. GOODACRE
RALPH W. PHILLIPS

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Special acknowledgments are due Cheryl Bell and Joan Justus for skillfully typing the manuscript and overseeing many other details related to the textbook while performing their regular secretarial duties.

The drawings in this text would not have been possible without the artistic assistance of W. J. Goodacre. His meticulous attention to detail is evident in the drawings. The skillful work of R. Scott, M. Halloran, A. Fears, R. Decastro, and M. Dirlam of the Department of Dental Illustrations at Indiana University School of Dentistry was essential to developing the clinical photographs which appear in this text.

We also appreciate the help given by M. R. Lund, M. A. Cochran, and T. J. Carlson of the Operative Dentistry Department at Indiana University School of Dentistry. Their willingness to review portions of the text associated with Operative Dentistry and to provide related illustrations was most helpful.

Many manufacturers have willingly supplied photographs and information. Their contributions have been acknowledged throughout the textbook.

The W. B. Saunders Company has been most helpful. Dental Editor Darlene Pedersen stepped in at a time when editorial assistance was greatly needed.

The acknowledgments would be most incomplete without mentioning those individuals who developed the foundation upon which the text was built. Dr. John F. Johnston and his wife Lavonne made by far the greatest contribution to the three previous editions of *Modern Practice in Crown and Bridge Prosthodontics*. Dr. Donald M. Cunningham contributed to these texts and was also instrumental in developing the textbook *Modern Practice in Removable Partial Prosthodontics*. The dedication to dentistry which was exhibited by these individuals continues to challenge us toward excellence.

CONTENTS

1

Introduction to the Discipline of Fixed Prosthodontics

Dentistry is the health science that encompasses the study and application of measures designed to prevent deterioration of the oral structures and the use of pertinent clinical procedures to improve the oral health of those treated. Among its many ramifications are the relief of pain, the treatment of oral diseases, the maintenance of masticatory efficiency, and the maintenance or restoration of the esthetic qualities of the mouth and face. One of the functions of dental practice, and one that is frequently overlooked, is to combine and coordinate research, educational, preventive, and clinical efforts so that an ever-increasing number of people can avoid the loss of teeth.

If the patient begins coming to the dentist early in life and is convinced of the dividends to be earned from a policy of preventive therapy, correct oral hygiene, and prompt repair of the tooth when a carious lesion has penetrated the enamel, there should be little need later for major restorative operations (Fig. 1–1). If a tooth must be lost, it is the duty of the dentist to inform the patient that the space should be filled as soon after surgery as healing and shaping of the ridge tissue are complete. The significance of keeping the arches intact must be stressed, since the loss of one tooth can effect changes in positions and contact relationships of all teeth remaining in the mouth.

If a fixed prosthesis is inserted soon after the loss of a tooth, the patient should benefit in many ways. The prosthesis should contribute to mastication; it should augment the ability of the patient to enunciate; it should

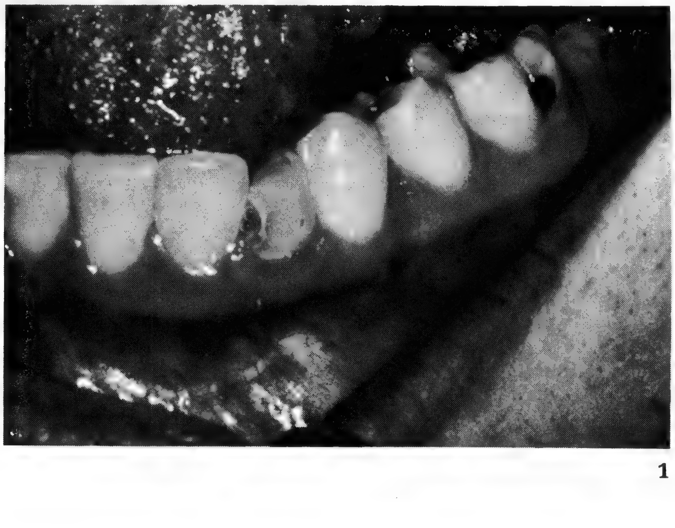


FIGURE 1–1 Extensively carious mandibular canine. Note loss of arch length caused by deterioration of tooth and mesial drifting of posterior teeth. The extent of caries necessitates endodontic treatment and restoration of the tooth, which will be mechanically and esthetically difficult owing to loss of space.

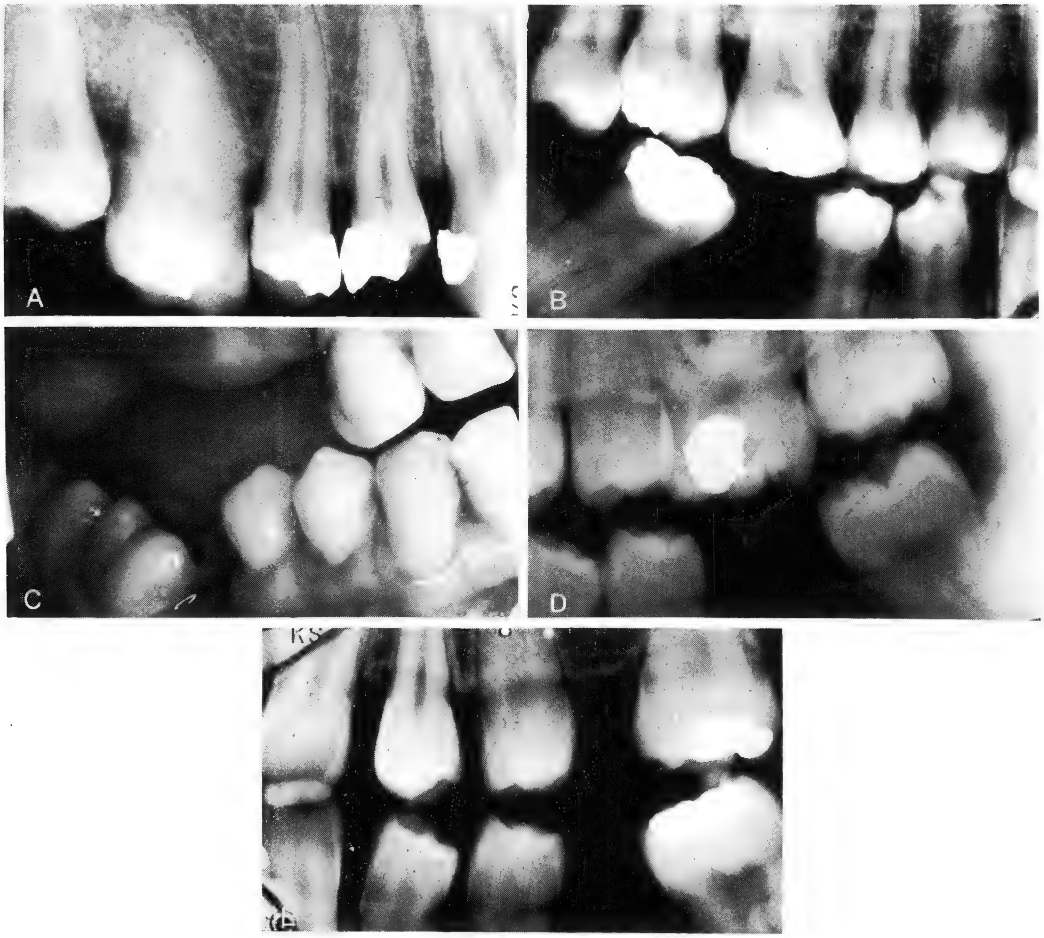


FIGURE 1–2

A, Failure to replace a missing mandibular molar has allowed the opposing maxillary first molar to erupt into edentulous space.
B, The mandibular second molar has tipped mesially owing to loss of the first molar.
C, Mandibular second and third molars have collapsed into the space previously occupied by the first molar.
D, Radiograph of an adolescent patient with the mandibular first molar already lost. The maxillary first molar is nonrestorable and must be removed.
E, Thirteen months later. Note that the premolars have drifted distally.

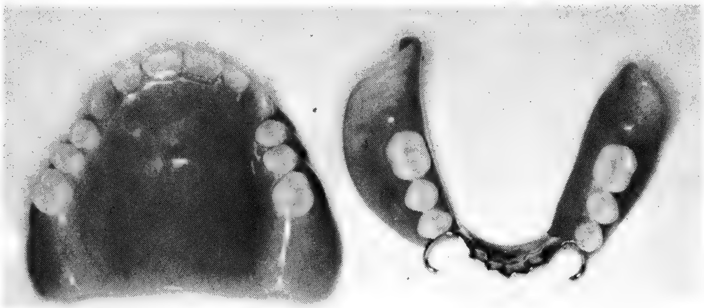


FIGURE 1–3 Two removable prostheses; complete and removable partial denture.

restore and preserve contacts between the abutments and the approximating teeth and also all other teeth in the arch; and it should maintain the positions of the opposing teeth and the health of the supporting structures.

When a space is unrestored for a long time, there will be some shifting of positions of the teeth approximating the edentulous areas and possibly extrusion of the opposing teeth (Fig. 1–2). Even here the replacement should substantially aid mastication, help reinstate contacts of appropriate strength, size, and location, and improve the health of the periodontium and prevent further injury.

DEFINITION OF TERMS

In order that subsequent discussion may be understood readily, terminology must be clarified. The first four definitions are those adopted by the Commission on Dental Accreditation of the American Dental Association.

Prosthodontics is that branch of dentistry pertaining to the restoration and maintenance of oral function, comfort, appearance, and health of the patient by the restoration of the natural teeth or the replacement of missing teeth and contiguous oral and maxillofacial tissues with artificial substitutes, or by both.

FIGURE 1–4 Mandibular fixed prosthesis replacing first molar.

Removable prosthodontics is that branch of prosthodontics concerned with the replacement of teeth and contiguous structures for edentulous or partially edentulous patients by artificial substitutes that are removable from the mouth (Fig. 1–3).

Fixed prosthodontics is that branch of prosthodontics concerned with the replacement or restoration of teeth, or both, by artificial substitutes that are not removable from the mouth (Fig. 1–4).

Maxillofacial prosthetics is that branch of prosthodontics concerned with the restoration or replacement, or both, of stomatognathic and associated facial structures by artificial substitutes that may or may not be removed (Fig. 1–5).

A *prosthesis* is any artificial replacement of a missing body part.

A *crown* is an artificial replacement that restores missing tooth structure by surrounding most or all of the remaining structure with a material such as cast metal (Fig. 1–6), porcelain (Fig. 1–7), or a combination of materials such as metal and porcelain (Fig. 1–8). It is intended to reproduce both the form and the function of the tooth and, in some instances, to restore or enhance the appearance.

A *full veneer crown* is an extracoronal restoration that involves all or nearly all of the surface of the clinical crown of a tooth (see Fig. 1–6).

A *partial veneer crown* is a restoration that usually includes all but one surface of a tooth—hence the frequently heard but not completely accurate term, *three-quarter crown* (Fig. 1–9).

A *fixed prosthesis*, or *fixed bridge*, is a nonremovable prosthesis that is rigidly attached to one or more abutment teeth to replace one or more lost or missing teeth (Fig. 1–9A, B). The term *fixed partial denture* is sometimes used.

The *abutment* is the natural tooth or teeth, usually two or more, that supports the prosthesis and to which it is attached (Fig. 1–9A, B).

The *retainer* is the restoration, usually a crown, rebuilding the prepared abutment tooth, by which the bridge is attached to the abutment and to which the pontic is connected (Fig. 1–9A, B).

The *pontic* is the substitute for the lost tooth, both esthetically and functionally (Fig. 1–10).

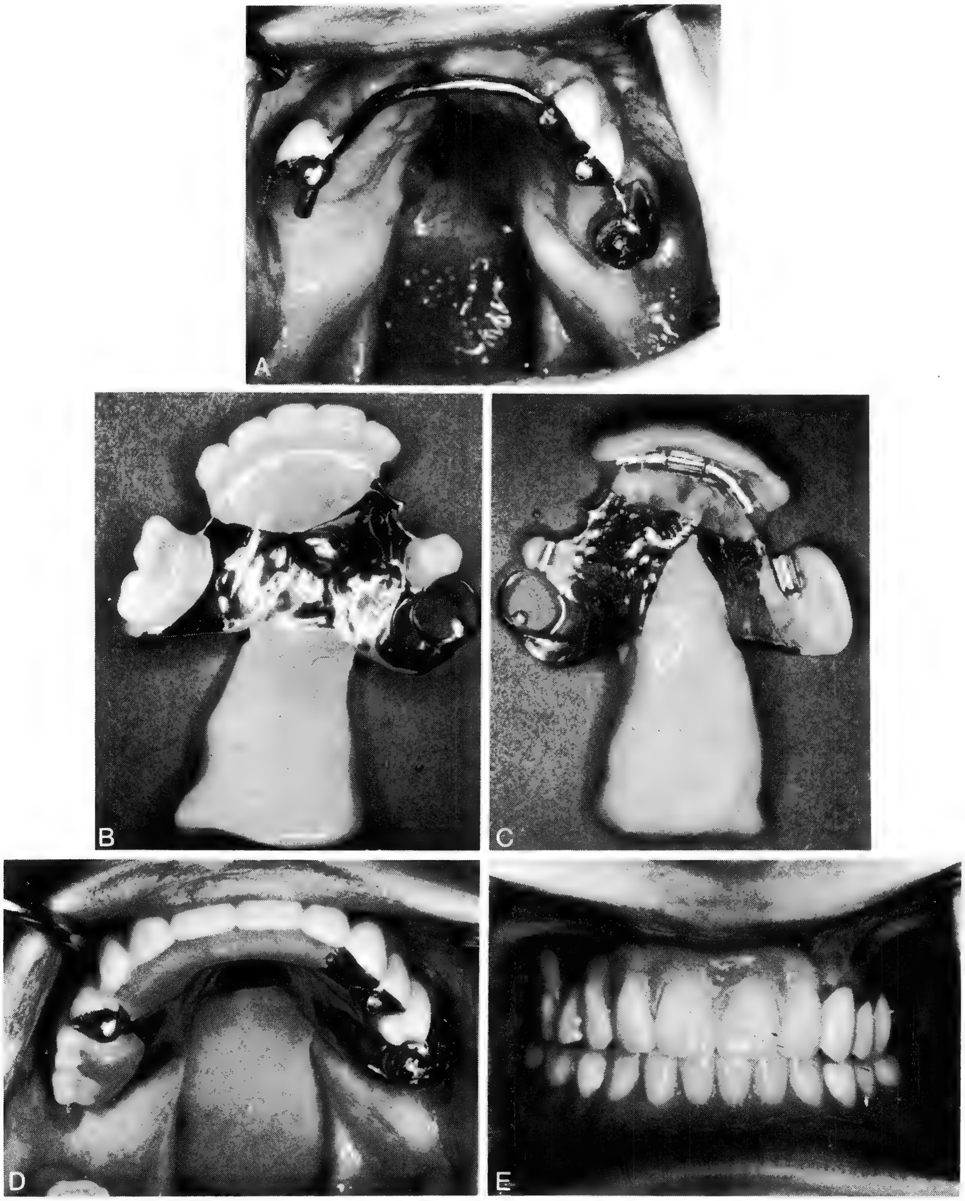


FIGURE 1–5

A, Palatal view of unrepaired cleft of the palate after periodontal and restorative treatment used in preparation of the mouth. The cross-arch splinting utilized an 11-gauge bar. This was necessary because of reduced alveolar bone support and the isolated right premolar.
B, C, Oral and tissue sides of the maxillary prosthesis with velar and pharyngeal sections attached to the partial denture so that it will function as a speech-aid prosthesis.
D, E, Palatal and anterior views of prosthesis in the mouth.

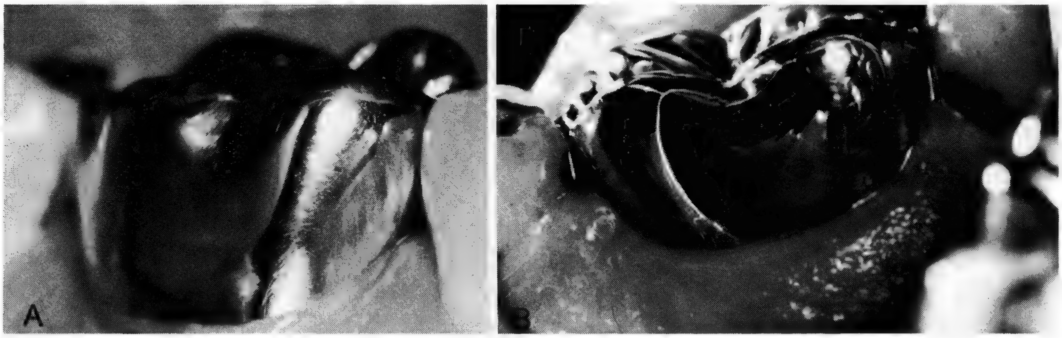


FIGURE 1–6

A, Facial view of mandibular molar, full veneer cast gold crown.
B, Lingual view.

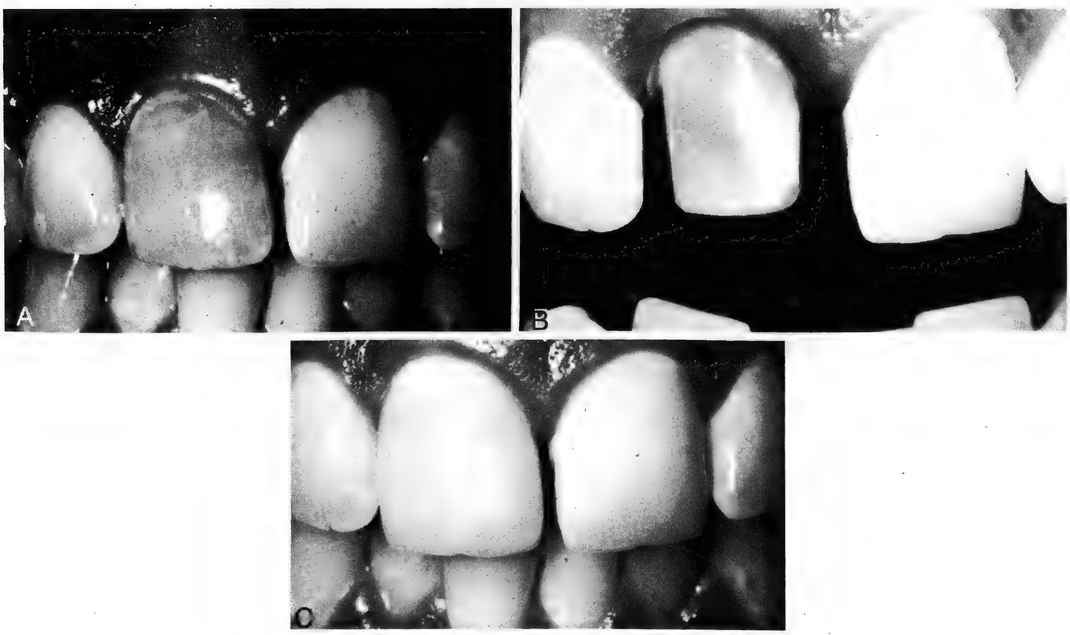


FIGURE 1–7

A, Discolored pulpless maxillary right central incisor.
B, Tooth prepared for porcelain jacket crown.
C, Crown cemented.

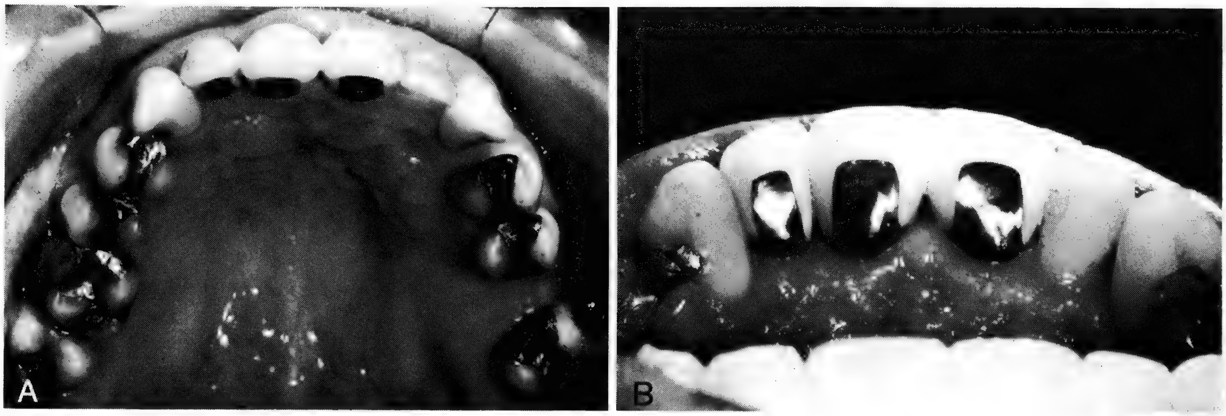


FIGURE 1–8

A, Metal-ceramic crowns on three maxillary incisors.
B, Lingual view.

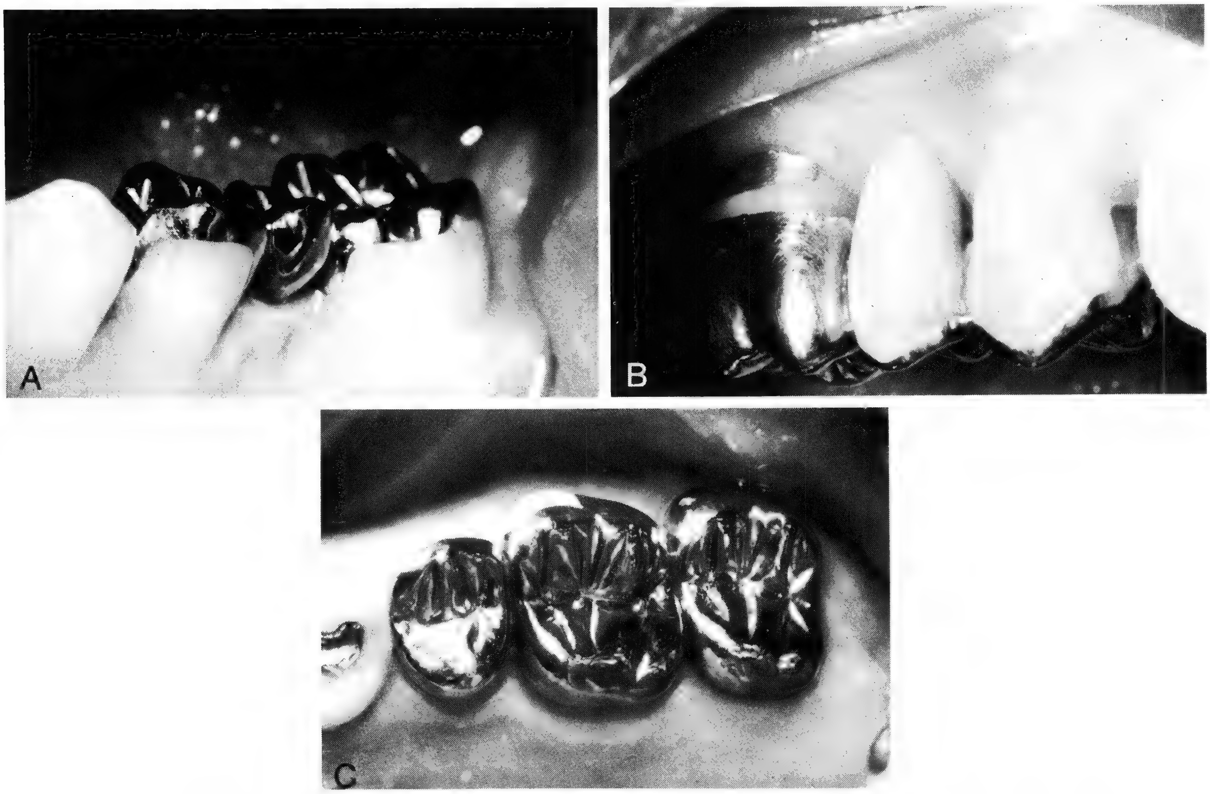


FIGURE 1–9

A, Fixed prosthesis (fixed bridge) using partial veneer crown retainers on the premolar and molar abutments.
B, Maxillary fixed prosthesis using partial veneer crown retainer on the first premolar and a full veneer crown retainer on the first molar.
C, Occlusal view of three single crowns. A partial veneer crown (three-quarter crown) was used to restore the second premolar. The first molar has a partial veneer crown (seven-eighths), and the second molar has a full veneer crown.

The *joint* or *connector* is the part of the fixed prosthesis that unites the retainer with the pontic or that joins the individual units of the prosthesis. It may be rigid, as are both the cast and soldered joint (Fig. 1–10), or nonrigid, as is the dovetail joint.

A *removable partial denture* is a prosthesis that replaces teeth and contiguous structures for partially edentulous patients. It can be removed from the mouth by the patient during oral hygiene procedures and for other purposes (Fig. 1–11).

The term *removable bridge* is sometimes applied to a removable partial prosthesis that is fully tooth-supported (Fig. 1–12). Many patients erroneously call removable partial dentures "removable bridges" or just "bridges."

Additional terms appearing later in the text will be defined as they are used.

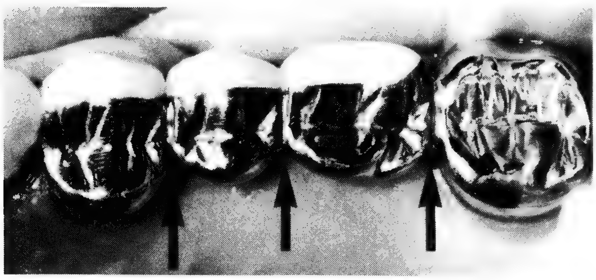


FIGURE 1–10 Maxillary fixed prosthesis using metal-ceramic pontics to replace the second premolar and first molar. Three joints are indicated by arrows. The joint between the molar units is soldered, the others are cast.

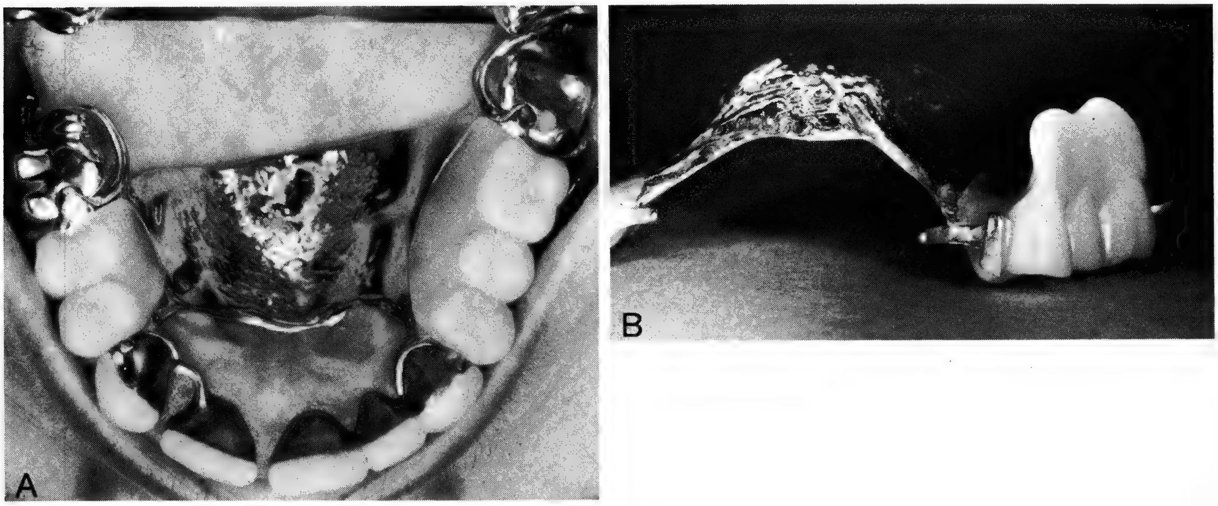


FIGURE 1–11
A,B, Maxillary removable partial denture using clasps and intracoronal attachments.

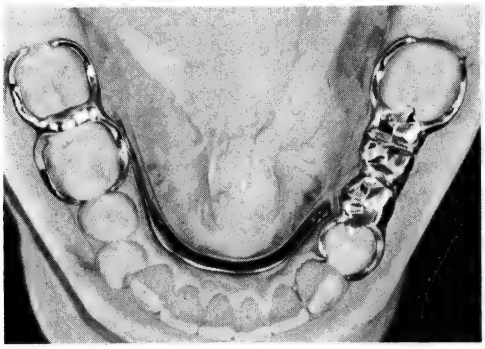


FIGURE 1–12 Mandibular removable bridge.

2

Diagnosis and Treatment Planning

Many failures of fixed prostheses can be attributed to treatment instituted without thorough consideration of all of the available facts. The objectives of any oral rehabilitative procedure are to increase masticatory efficiency, to retain the remaining teeth and preserve their supportive tissues, and to achieve the best possible esthetic effect. This is true whether the treatment involves the restoration of normal function to a single tooth or the reconstruction of the entire dentition. To achieve these objectives, a treatment plan must be derived from a thorough and accurate diagnosis.

Diagnosis is the process used to identify an existing abnormal condition, to investigate the abnormality, and to determine its cause. In general, a logical evaluation may be made from the data obtained from dental and medical histories, extraoral and intraoral examinations, a radiographic survey, pulp testing, exploration of all associated teeth and other teeth with questionable restorations or carious lesions, articulated diagnostic casts, and a survey analysis.

GENERAL DIAGNOSTIC FACTORS

A pertinent medical history should be elicited using some well-chosen questions. The patient should be asked whether he or she is under a physician's care and, if so, which drugs are being administered. The date and relevant findings of the last physical examination should be recorded. An examination within the year is desirable and certainly should be requested of patients over 40 years of age. Serious illnesses, past or present, should be noted, especially those involving the cardiovascular or respiratory systems, since these might necessitate prophylactic or remedial medications before and during dental treatment. Since the incidence of subacute bacterial endocarditis is significantly higher than average in patients with a history of rheumatic fever or congenital heart disease, a positive history of either condition indicates prophylactic medication before any dental operations are begun that could result in transient bacteremia.

Coronary thrombosis is not uncommon, particularly in men past middle age. These patients may be taking anticoagulant drugs, and therefore treatment that might cause hemorrhage of any magnitude is contraindicated until medical treatment has been begun to restore the normal coagulating mechanisms of the blood.

A history of hypertension suggests that appropriate measures should be taken to relieve the patient's fear or apprehension during treatment, thereby reducing the possibility of cardiovascular accidents. It would be wise to use local anesthetics not containing vasopressor drugs.

Allergic manifestations, either to drugs—such as aspirin, iodine, local anesthetics, eugenol, mercury, penicillin, or other antibiotics—or to foods, cannot be ignored; otherwise the life of a patient may be endangered. Competent medical consultation must be sought if there is any doubt regarding the present physical status of the patient.

Information about periodontal disease, malocclusion, or other facial or dental deformities in the family, dental experiences, and recent therapy should be complete in the dental history. Causes for the loss of teeth (such as caries or periodontal disease) and complications following extractions or other dental measures should be learned. The patient's attitude toward and understanding of good oral hygiene must be a part of every dental history, since the success or failure of dental treatment involving replacement of teeth can be directly related to the patient's willingness and ability to maintain satisfactory posttreatment care.

Extraoral observation reveals the facial profile and any asymmetry and deviations from normal on opening and closing of the mandible. The skin of the face and neck should be observed for possible variations in color, texture, pigmentation, eruptions, or lesions that would suggest local or systemic disease.

The neck should be palpated for the presence of lymphadenopathy or glandular enlargement. Lymph node enlargement is suggestive of acute or chronic infections of regional or systemic origin. In the absence of infection, enlarged lymph nodes may be a sign of neoplastic disease, and this possibility must be negated.

Palpation of the temporomandibular joints and acces-

sible muscles of mastication on opening and closing of the jaw should disclose whether movements are smooth and free from jerky or spastic action and reveal the presence of swelling or tenderness. The reasons for any eccentricities should be ascertained.

Oral examination should begin with a search for pathologic conditions on the lips, buccal mucosa, gingiva, tongue, palate, floor of the mouth, and pharynx, as evidenced by abnormal size, color, or surface contour, and should include palpation for the presence of lymphadenopathy or neoplastic disease.

The lips should be examined for signs of early malignant neoplastic disease or precancerous lesions. Any lesion present for two weeks or more should be considered neoplastic until proved otherwise. Biopsy may be indicated.

The buccal mucosa is a prevailing site of leukoplakia, lichen planus, and areas of chronic irritation. Malignant changes sometimes occur in the presence of these conditions; therefore, chronically abnormal areas should be inspected periodically.

The gingiva is often a mirror of systemic diseases: anemia, leukemia, polycythemia, and Addison's disease are examples of those diseases with oral manifestations affecting the gingival tissues.

As a rule, lesions of the tongue are traumatic in origin. However, local and systemic pathologic involvement is observable in many instances. Most common are carcinoma, tuberculosis, syphilis, pernicious anemia, herpes, and glossitis of vitamin deficiencies.

The palate may show a variety of pathologic conditions. Localized lesions from trauma or of herpes, necrotizing ulcerative gingivitis, and hyperkeratosis are common. Systemic lesions of tuberculosis or syphilis are seen in a few cases.

The floor of the mouth can have lesions that are cystic. An early differential diagnosis to rule out malignant neoplastic disease is very important.

The oropharynx can be the site of both local and systemic disease. Lesions in this area that show poor or nonhealing tendencies should be referred for medical appraisal. A malignant neoplastic disease in this area must be found and treated soon after its inception if it is to be cured.

The maxillomandibular relationship should be observed, especially relative to closure in centric relation, so that premature occlusal contacts causing a mandibular shift may be detected. Tooth contacts in eccentric movements of the mandible should also be noted.

Investigation of individual teeth should start with a dental prophylaxis so that each tooth surface and adjacent investing tissues may be viewed critically when seeking carious or precarious lesions, restorations with defective margins, exposed or sensitive root surfaces, erosion, and attrition. Tooth mobility, open contacts, areas of food impaction, and periodontal pockets can be tabulated at the same time. Another examination one to two weeks later shows the response of the gingiva to the removal of irritants and helps to determine the extent of future periodontal therapy. At this visit impressions for diagnostic casts also may be made with the teeth free of debris and the tissue contour normal.

The radiographic examination should include a minimum of 14 periapical films and both right and left posterior bite-wing films. Lateral jaw, cephalometric, panoramic, or temporomandibular joint radiographs may be needed in special cases. Radiographs of good quality disclose the presence of osseous disease, locations and approximate depth of carious lesions, widths and lateral positions of the pulps, crown-root ratios, root sizes and forms, widths of the periodontal membranes, quality of restorations, presence of root fragments or foreign bodies, character of bone in areas of added stress (such as tipped teeth, traumatic occlusion, bridge abutments, and so forth), surface character of the alveolar ridge in edentulous areas, and possibly provide information for an evaluation of bone density.

It is always advisable to test the vitality of the pulps in the remaining teeth because this may show that a tooth that is necessary in the design of the proposed prosthesis is nonvital. Should such a tooth be untreatable, its loss could change the design of the prosthesis. Any one of the low-voltage pulp testers will suffice in most cases, but in doubtful situations the response to alternate applications of heat and cold is useful also.

In many instances the only reliable method for determining the strength and worth of a tooth is direct exploration, that is, the mechanical removal of all restorations and caries. A scrutinous inspection for pulpal exposure and determination of the amount and distribution of the remaining dentin must then be made. After temporary restoration of the lost tooth structure, enough time (four to six weeks minimum) should be allowed for the results of the treatment to become known.

Diagnostic casts are reproductions of the patient's maxillary and mandibular arches. They are needed as a source of information in reaching the diagnosis. The casts must accurately copy all teeth and the surrounding soft tissue that are important to the fabrication of the prosthesis. They also must include all areas that are necessary to make custom impression trays for later use. Duplication of occlusal contours is necessary to enable accurate mounting of the casts in an articulator (see Chapter 9) in order to analyze the occlusion. Information regarding diagnostic cast making is found at the end of this chapter.

Articulated diagnostic casts allow an opportunity for a leisurely and detailed study of tooth relationships in the various movements of the mandible. With these findings and the knowledge gained from the clinical examination, a determination can be made regarding occlusal adjustments that will be mandatory to consummate a harmonious physiologic occlusion prior to the restorative phase of treatment.

INDICATIONS FOR FIXED PROSTHESES

A fixed prosthesis is indicated whenever properly distributed and healthy teeth exist to serve as the abutments, provided that these teeth have suitable crown-root ratios and, on the basis of radiographic, diagnostic cast, and oral examinations, seem capable of sustaining the additional load. In general, a fixed prosthesis is preferred to a removable prosthesis.

There are many factors related to the teeth and to the immediately adjacent oral structures that have direct influence on the success or failure of an individual restoration or fixed prosthesis. Careful attention must

be given to all of them if the treatment is to aid in the preservation of the remaining dentition. While all of the following factors relate to fixed prostheses, many of them apply as well to single restorations.

FACTORS INFLUENCING DESIGN

Crown Length

Teeth must have adequate occlusocervical crown length to achieve sufficient retention. Teeth with short clinical crowns often do not provide satisfactory retention unless full-coverage preparations are used or additional length is achieved through periodontal surgery (Fig. 2–1).

Crown Form

Some teeth have a tapered crown form, which interferes with preparation parallelism, necessitating full-coverage retainers to improve their retentive and esthetic qualities (Fig. 2–2). Examples include anterior teeth that have poorly developed cingula and short proximal walls and mandibular premolars with poorly developed lingual cusps and short proximal surfaces. Also, some incisors possess very thin highly translucent incisal edges, making the use of partial coverage retainers esthetically unacceptable.

Degree of Mutilation

The size, number, and location of carious lesions or restorations in a tooth affect whether full- or partial-coverage retainers are indicated (Fig. 2–3A). Also, teeth may be so fractured or carious that they are not restorable and should be removed, thereby creating the need for a prosthesis or altering its original design (Fig. 2–3B).

Root Length and Form

Abutment teeth must retain stability for the prosthesis to function normally and to preserve the health of the mouth. Stability requires anchorage in an amount of bone adequate to resist the occlusal forces that will be transmitted to the abutment teeth. Roots with parallel sides and developmental depressions are better able to resist additional occlusal forces than are smooth-

FIGURE 2–1 A short clinical crown on the second premolar necessitated the use of a full veneer crown.

FIGURE 2–2 Malformed teeth with tapered form requiring full coverage to achieve adequate retention and esthetics.

sided conical roots. Also, multirooted teeth generally provide greater stability than single-rooted teeth (Fig. 2–4).

Crown-Root Ratio

A comparison of the tooth length projecting out of the alveolar bone and the length embedded in bone has traditionally been used as a guideline in determining the suitability of a tooth as an abutment. The higher the ratio, the less likely the tooth will be able to withstand additional occlusal forces. The problem becomes even greater when nonaxial (faciolingual) forces are brought to bear on the prosthesis.

A 1:1.5 ratio has generally been considered to be satisfactory (Fig. 2–5A), whereas a 1:1 ratio is considered minimal (Fig. 2–5B) and requires consideration of other factors (such as the number of teeth being replaced, tooth mobility, and overall periodontal health) before a tooth having such a crown-root ratio is considered for use as an abutment.

Ante's Law

Abutment support may be evaluated by employing a rule, often referred to as "Ante's Law," that, paraphrased, says that the combined periodontal ligament area of the abutment teeth should equal or exceed that of the tooth or teeth to be replaced. While latitude must be used in applying this rule, it is a safe and useful guideline when employed along with the other factors to be considered in the evaluation of abutment capabilities.

Periodontal Health

Inadequate periodontal health often results in bone loss that alters the suitability of a tooth to support a fixed prosthesis (Fig. 2–5B). Extensive bone loss may require the use of multiple abutment teeth, a removable prosthesis, or even tooth extraction. If periodontal disease is present, it must be eliminated before definitive restorative treatment is begun, and the patient must receive and adequately respond to instruction in proper oral hygiene procedures. An evaluation of the response to periodontal treatment is an important part of the

FIGURE 2–3
A, Molar abutment requiring full coverage because of large existing restoration.
B, Excessive caries requiring extraction of tooth.

FIGURE 2–4
A, Relatively short converging molar roots affording less than average support for fixed prosthesis.
B, Longer straight roots. Molar exhibits diverging roots, which provide better support.

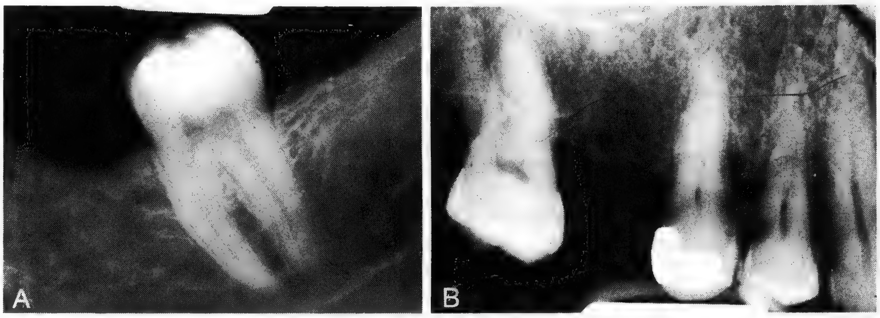


FIGURE 2–5
A, Crown-root ratio of mandibular molar is 1:1.5.
B, Maxillary molar and second premolar having crown-root ratios of 1:1.

diagnostic process, which must be concluded before restorative treatment is begun.

The selection of retainers and pontics must be planned to promote effective oral hygiene and must not become a hindrance. Also, designs must take into account patients with compromised dexterity or those who practice minimally acceptable oral care. In some cases, periodontal health is best maintained with a removable prosthesis.

Mobility

Teeth with greater than normal mobility are frequently capable of being used as abutments for a fixed prosthesis and should not automatically be considered unsuitable. The magnitude of the mobility and its cause must be evaluated. A Miller mobility value of one is generally acceptable, whereas a mobility value of two requires assessment of the cause and consideration of the number of teeth being replaced. If the mobility is related to deflective occlusal contacts (Fig. 2–6) that can be eliminated and if a short-span prosthesis is involved, the tooth is likely to be a suitable abutment. If the mobility is caused by considerable bone loss and more than one tooth is to be replaced, it is unlikely that the tooth would be a suitable abutment unless it can be splinted to another sound tooth. A tooth with a mobility value of three is not suitable as an abutment.

FIGURE 2–6 Radiograph of mobile maxillary premolar. Note the widened periodontal ligament space. Correction of occlusion reduced the mobility to normal.

Span Length

The distance between abutment teeth affects the feasibility of placing a fixed prosthesis. Replacement of one tooth is routinely accomplished with a fixed prosthesis, as is generally the replacement of two approximating missing teeth. However, the loss of three adjacent teeth requires careful evaluation of other factors such as crown-root ratio, root length and form, periodontal health, mobility, and occlusion (Fig. 2–6).

Fixed prostheses replacing four adjacent teeth are sometimes fabricated but only in anterior areas of the mouth in which reduced occlusal forces are encountered.

Axial Alignment

The crowns of proposed abutment teeth must be sufficiently well aligned that retentive preparations can be developed. Malalignment of abutment teeth can be so severe that it prevents placement of a fixed prosthesis without devitalization of the teeth or orthodontic movement to correct the malalignment (Fig. 2–7).

Minor alterations in axial alignment (tipped or rotated teeth) often necessitate the use of full-coverage retainers either to achieve adequate retention or to obtain acceptable esthetic results.

Arch Form

A curvature in the arches often places pontics facially to a straight line (the *fulcrum line*) drawn between the teeth immediately adjacent to the edentulous area. This relationship creates a lever arm, which can exert excessive forces on the abutment teeth when occlusion occurs on the pontics. The forces can exceed the capacity of these teeth to resist tipping, depending on the length of the lever arm and the magnitude of the forces applied. As a general rule, counter-balancing retention must be provided to offset the lever arm length. Retention on additional teeth ideally should extend at least as far behind the fulcrum line as the pontics are located ahead of the fulcrum line (Fig. 2–8).

FIGURE 2–7 Anterior inclination of the maxillary canine will result in pulp exposure if the canine is prepared parallel with existing premolar preparation.

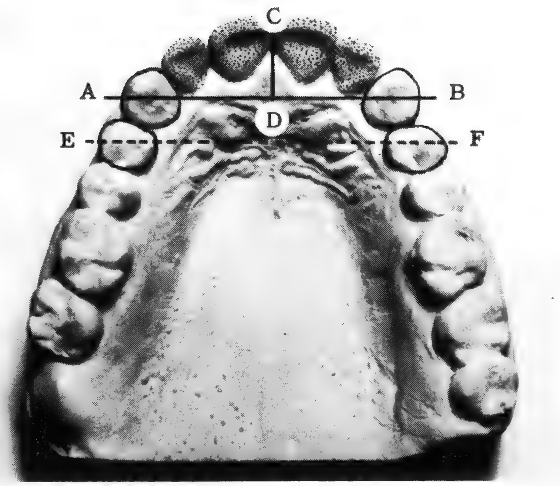


FIGURE 2–8 Line AB represents the fulcrum line. Line CD indicates the distance the pontics extend anteriorly to the fulcrum line. Line EF represents counter-balancing retention afforded by including first premolars as abutments.

Occlusion

The occlusal forces brought to bear on a prosthesis are related to the degree of muscular activity; the patient's habits, such as bruxism; the number of teeth being replaced; the leverage on the bridge; and the adequacy of bone support. Excessive occlusal forces can cause loosening of the prosthesis through flexure or can induce fracture when a ceramic component is present. The forces can also cause tooth mobility, particularly in the presence of decreased bone support.

Pulpal Health

Abutment teeth with poor pulpal health should receive endodontic treatment prior to tooth preparation. Full-coverage retainers are required on most endodontically treated teeth to minimize the chances of tooth fracture. Also, a post and core may be necessary to augment the retention afforded by the remaining tooth structure.

Alveolar Ridge Form

When there has been considerable loss of alveolar process, such as often occurs with the loss of teeth caused by a traumatic injury, the space created may be too large to allow the use of pontics of normal size and length. In addition, such a defect may not allow the pontics to be positioned to best support the lips and cheeks and restore normal facial form (Fig. 2–9). Both situations may indicate the use of a removable prosthesis rather than one that is fixed.

Age of the Patient

Fixed prostheses are usually contraindicated in the mouths of adolescents when the teeth are not fully

FIGURE 2–9 Maxillary arch with gross loss of alveolar bone. The facial contour must be restored with the base of a removable partial denture.

erupted or when the pulps are excessively large and prohibit retentive preparations. If a bridge is not to be made, then a space-maintainer should be inserted to hold the abutments and opposing tooth position.

If the condition of the abutment teeth necessitates full-coverage restorations, a fixed prosthesis should be considered. However, tooth reduction depth should be kept to a minimum, and the prosthesis should be considered temporary, to be remade when pulp size permits.

Phonetics

The replacement of missing teeth with fixed prostheses generally provides sufficient resistance to the flow of air to allow normal speech sounds to be produced. However, the design of certain pontics or the existence of a large alveolar bone defect may not allow pontics to help the patient produce normal phonetics as well as a removable prosthesis does.

Long-term Abutment Prognosis

When there is some question of the ability of the remaining supporting structures to accept additional occlusal forces, the bilateral bracing afforded by a removable prosthesis may be advantageous. Also, a tooth with sufficient loss of periodontal support and questionable long-term prognosis may best be treated with a removable prosthesis.

Esthetics

In most situations, fixed prostheses provide the most esthetic means of replacing missing teeth. However, an intracoronal attachment removable prosthesis is often esthetically advantageous when there is a large defect in the edentulous ridge or when several teeth are missing and diastemas are required. A removable prosthesis may also be indicated when the use of a pontic produces large and unsightly proximal embrasures in a fixed prosthesis.

Psychologic Factors

To most patients a fixed partial denture feels more normal than a removable prosthesis and more quickly becomes an accepted part of the oral environment. The thought of wearing a removable prosthesis is difficult for some patients to accept. These reasons support the use of fixed prostheses rather than removable prostheses whenever possible.

Summary

It must be realized that all these complex factors cannot be readily defined or positioned in order of significance. Relative importance changes with individual mouths. In fact, each new patient presents new problems and new difficulties to the novice. Increased knowledge in diagnosis and treatment planning will be gained as these principles are applied to the examples cited throughout the text so that the reader can learn to make use of such diagnostic information automatically. The contents of this chapter and those that follow should equip the student of dentistry with a firm foundation for professional growth.

DIAGNOSTIC CASTS

Both reversible hydrocolloid and the nonaqueous elastomeric impression materials are excellent for making diagnostic casts. These materials are more accurate than alginate (irreversible hydrocolloid). However, alginate is sufficiently accurate for use in making diagnostic casts and usually is the preferred impression material because it is simple and convenient to handle in comparison with other impression materials. Obtaining adequate accuracy with alginate requires a knowledge of the material and its proper handling.

Alginate (Irreversible Hydrocolloid)

The chief ingredient of the irreversible hydrocolloid impression materials is a soluble salt of alginic acid. When mixed with water and other chemicals in the powder, the soluble alginates form a viscous sol, which in turn hardens to form a gel by an irreversible chemical reaction.

Shelf Life

Alginate impression materials deteriorate rapidly at elevated temperatures. Materials that were stored for one month at 65° C (149° F) proved to be unsuitable for dental use, either failing to set at all or setting much too rapidly. Even at 54° C (129° F) there was evidence of deterioration, which probably was caused by depolymerization of the alginate constituent. It is best not to stock more than one year's supply and to store the material in a cool dry environment.

The alginate material is dispensed to the dentist in individually sealed pouches containing sufficient powder preweighed for an individual impression or in bulk form in a can. The individual pouches are preferable, since there is less chance for contamination during storage, and the correct water-powder ratio is ensured, since plastic cups are provided for the measurement of the water. However, the bulk form of packing is by far the most popular.

If the bulk package is employed, the lid should be firmly replaced on the container as soon as possible after each use so that a minimal amount of contamination with moisture occurs.

Ideally the powder should be weighed and not measured by volume in the scoop provided by the manufacturer. However, unless a grossly incorrect method of scooping the powder is used, it is unlikely that a significant effect on the physical properties will occur.

If the powder in the can is fluffed before measurement, it is important to avoid breathing the dust, which rises from the can when the lid is removed. Some of the silica particles in the dust are of a size and shape to be a possible health hazard.

Gelation Time

The gelation time, measured from the beginning of mixing until the gelation occurs, is of interest, since sufficient time must be available for mixing the material, loading the tray, and placing it in the patient's mouth. A prolonged gelation time is tedious for both the patient and the dentist. On the other hand, a premature gelation, which begins before the filled impression tray has been placed in position in the mouth, results in a distorted and generally useless impression. Once the gelation starts, it must not be disturbed, because any fracturing of the gelling fibrils will be permanent. Probably the optimal gelation time is between three and four minutes at a room temperature of 20° C (68° F).

There are several methods for the measurement of gelation time, but probably the best clinical method is to observe the time from the start of mixing until the material is no longer tacky or adhesive when it is touched with a clean dry finger.

The best method for the dentist to use to control the gelation time is to alter the temperature of the water used in mixing the alginate material. The effect of the temperature of the water on the gelation time of an alginate impression material is shown in Figure 2–10. It is evident that the higher the temperature is, the shorter the gelation time will be. The importance of having the water at the proper temperature is evident. In hot weather, special precautions should be taken to provide cool water for mixing so that a premature gelation is not obtained. It may even be necessary to precool the mixing bowl and spatula, especially when small amounts of impression material are to be mixed. In any event, it is better to err by having the mix too cool than too warm.

Tray Selection

A stock tray is almost always satisfactory for use in obtaining the impressions. Perforated metal, perforated plastic, or metal rim-lock trays can be used. An advantage of plastic trays is that they are disposable, and therefore cleaning and sterilization are not necessary.

In those somewhat rare cases when a stock tray does not fit properly, the size closest to that desired may be used to obtain a cast, which, while not suitable for diagnostic purposes, may be altered if needed and used to construct a custom-made plastic tray (see Chapter 10 regarding the technique for constructing custom trays).

A tray is selected (Fig. 2–11) with a minimal clearance of 3.0 mm (one eighth inch) at all points, which accommodates a sufficient bulk of impression material that removal from undercut areas can occur without causing permanent deformation of the alginate. The tray must be tried in the mouth to validate the choice and to make certain that there is no impingement on the teeth or soft tissue. When impingement occurs, a larger tray should be selected, or if the next size is too large, the smaller tray can be reshaped by bending the metal or heating the plastic so it can be molded. Occasionally it is necessary to extend a border with wax to reach a vital area.

Plastic trays do not retain alginate as well as the metal trays, and it is advisable to coat the former with a thin layer of alginate adhesive. The adhesive helps to prevent separation of the gelled alginate from the tray when it is removed from the mouth. If the material separates from the tray, the impression cannot be considered accurate.

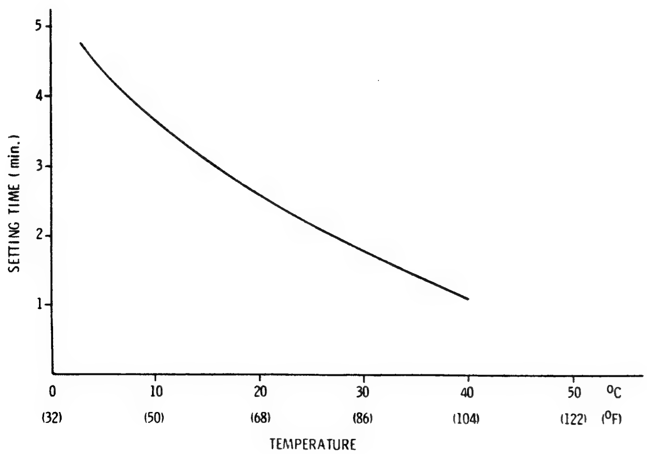


FIGURE 2–10 The effect of water temperature on the setting time of an alginate impression material. (Courtesy of J. Cresson. From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982.)

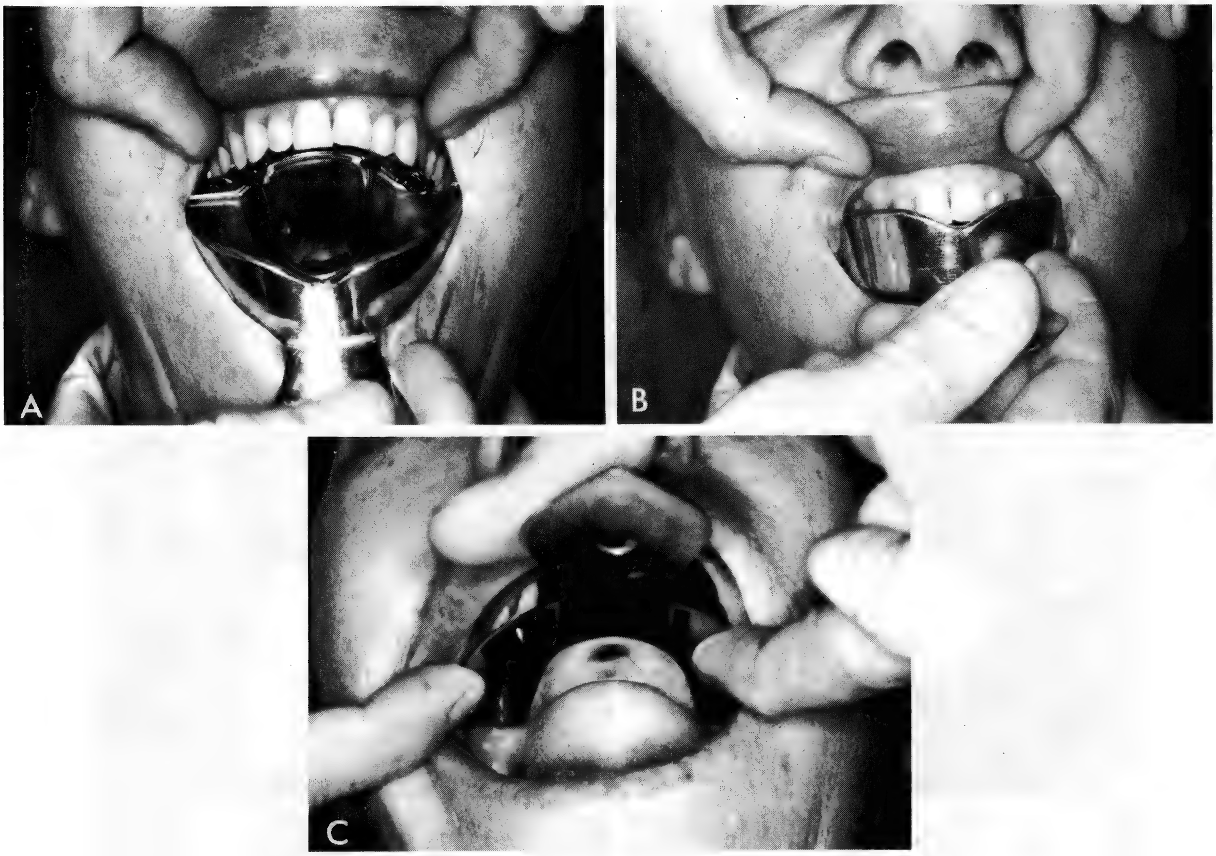


FIGURE 2–11 Tray Selection

A, Checking width of maxillary tray.
B, Checking anterior clearance.
C, Tray fully seated without impinging on teeth or soft tissue.

Preparing the Mouth for an Impression

After the tray has been selected and adapted, the patient's head is placed in an upright position so that the tray can be inserted into the mouth in a horizontal position. The mouth is rinsed with cool water to remove excess saliva and any other matter that may reduce the exactness of the impression.

Preparing the Mix

Although special plastic spatulas and bowls are available for mixing, generally a rubber bowl and metal spatula are employed. It is probably desirable to use separate bowls for mixing alginate and gypsum products, since contamination of the alginate with gypsum during mixing may result in too rapid a set, inadequate fluidity, or even rupture of the impression upon removal from the mouth.

Maximal gel strength is required in order to prevent fracture and to ensure elastic recovery of the impression when it is removed from the mouth. All the manipulative factors affect the gel strength. For example, the proper water-powder ratio as specified by the manufacturer should be employed. The mixing time is particularly important, since strength of the gel can be reduced by as must as 50 per cent if the mixing is not complete. Insufficient mixing with the spatula results in failure of the ingredients to dissolve sufficiently so that the chemical reactions can proceed uniformly throughout the mass. On the other hand, if the mixing time is unduly prolonged, the gel breaks up as it is forming, and the strength is decreased. The directions supplied with the product should be adhered to in all respects.

The correct amount of powder is placed in the water and incorporated by careful mixing with the spatula (Fig. 2–12). A mixing time of 45 seconds to one minute is generally sufficient, depending on the brand and type of alginate. The result should be a smooth creamy mixture that does not drip off the spatula when it is raised from the bowl. A variety of mechanical devices are also available for mixing the alginate materials. Their principal merits are convenience, speed, and the elimination of the "human variable."

Care should be taken during mixing to avoid whipping air into the alginate. A vigorous figure-eight motion is recommended, with the mix being swiped or "stropped" against the sides of the rubbing mixing bowl (Fig. 2–12). This is effective in working out most of the air bubbles

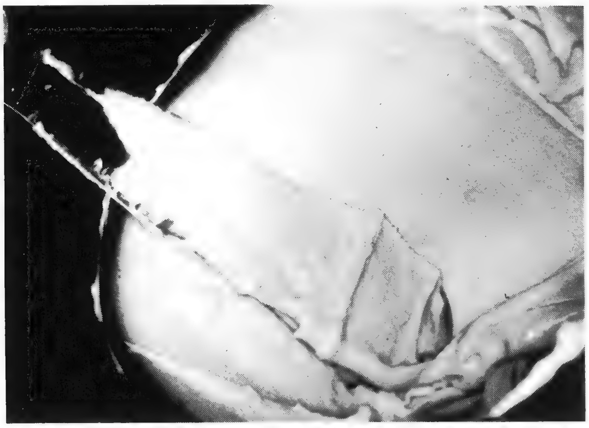


FIGURE 2–12 Mixing Alginate Impression Material
Wiping alginate against side of bowl.

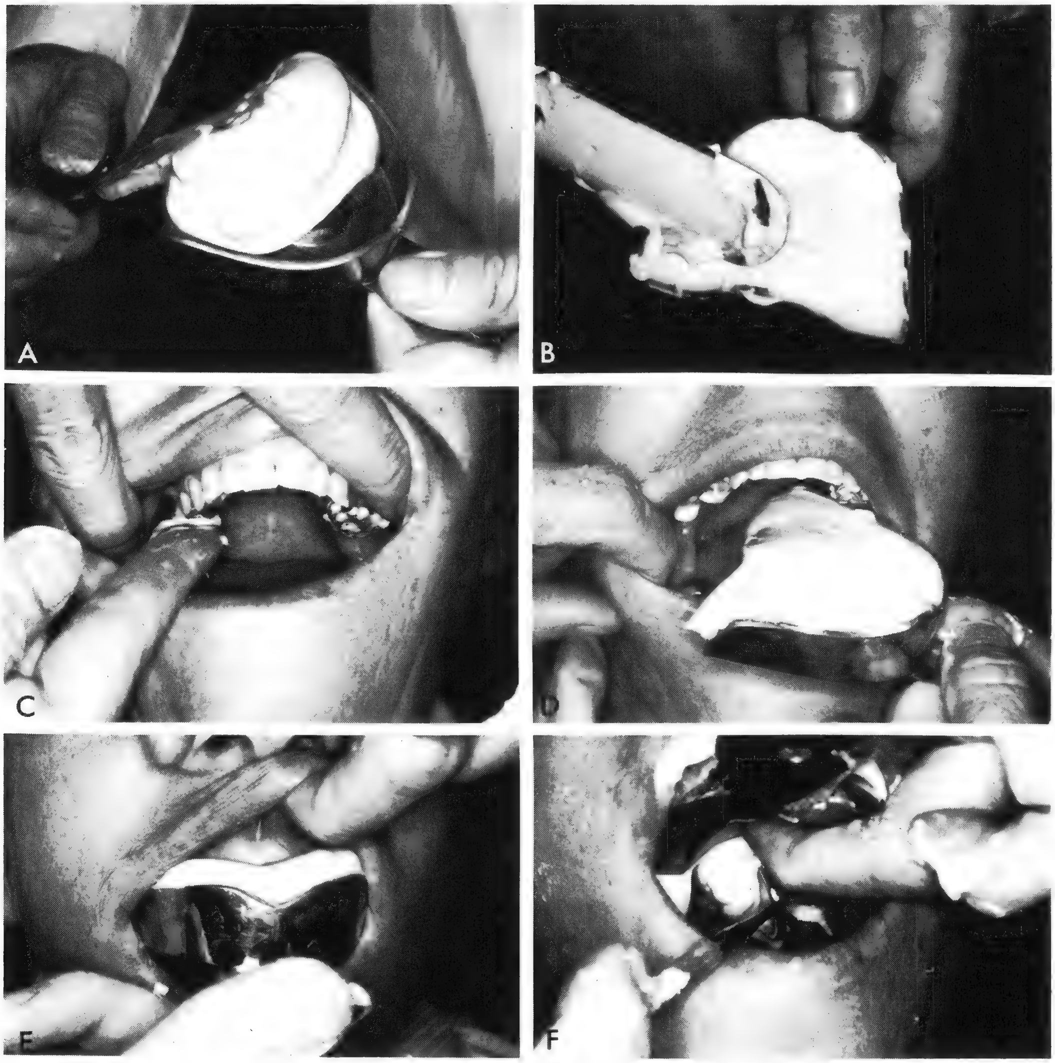


FIGURE 2–13

A, B, Loading maxillary tray.
C, Wiping impression material over occlusal surfaces.
D, Inserting tray. One cheek is being retracted with tray, while the other is retracted with a finger.
E, Lip is retracted to allow material to flow into labial fold.
F, Removing excess material from palate with mouth mirror.

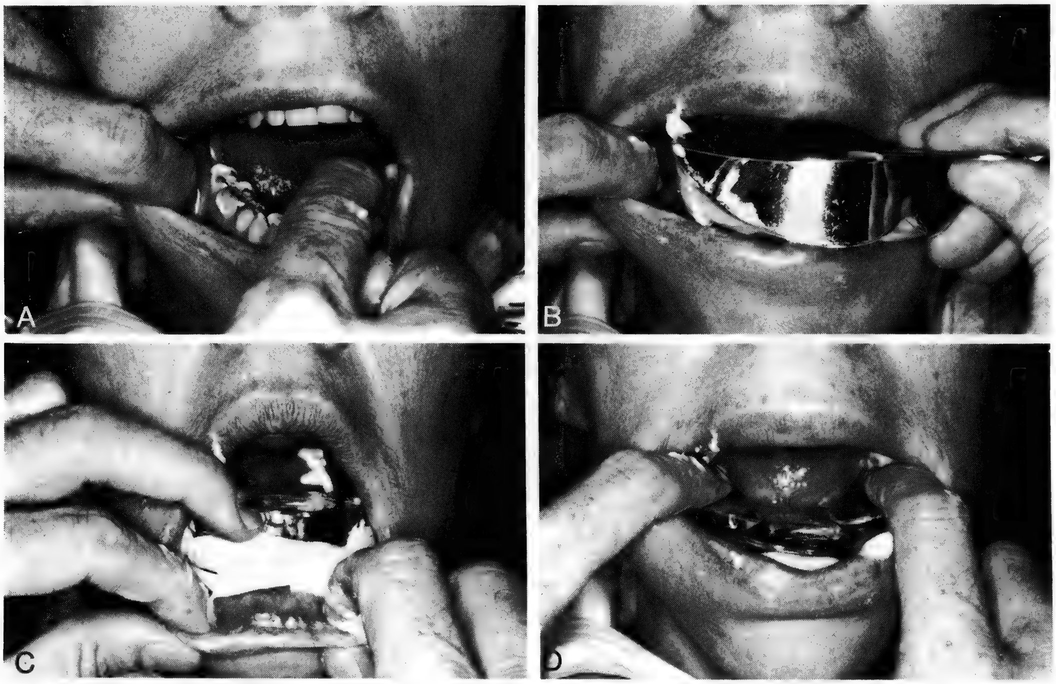


FIGURE 2–14

A, Wiping impression material over teeth.
B, Inserting tray while retracting cheeks.
C, Retracting lip.
D, Seating tray while patient raises tongue.

and also ensures complete dissolution of the powder, which is necessary to form a gel with good physical properties.

Making the Impression

The mixed material is loaded into the tray (Fig. 2–13A, B) and then, in order to prevent air from being trapped and producing voids in the impression, the material is rubbed over all surfaces of the teeth by the index finger (Fig. 2–13C). The tray is then inserted into the mouth (Fig. 2–13D, E, F). If a mandibular impression is being made, the patient is asked to raise the tongue before the tray is completely put in place, after which the tongue is relaxed. By this procedure the tongue is not caught under the tray, and the proper lingual soft tissue contours can be copied (Fig. 2–14).

When the tray is guided into position, overseating, with the resultant impingement of the tray on the teeth or soft structures, must be avoided. The patient should not swallow or move the mouth tissues in any other way, and the tray should be held motionless until gelation is complete (Fig. 2–15).

The strength of the alginate gel increases for several minutes after the initial gelation, and the elasticity of most alginate materials also improves with time, thus permitting superior reproduction of undercut areas.

FIGURE 2–15

A, B, Trays held motionless while material gels.

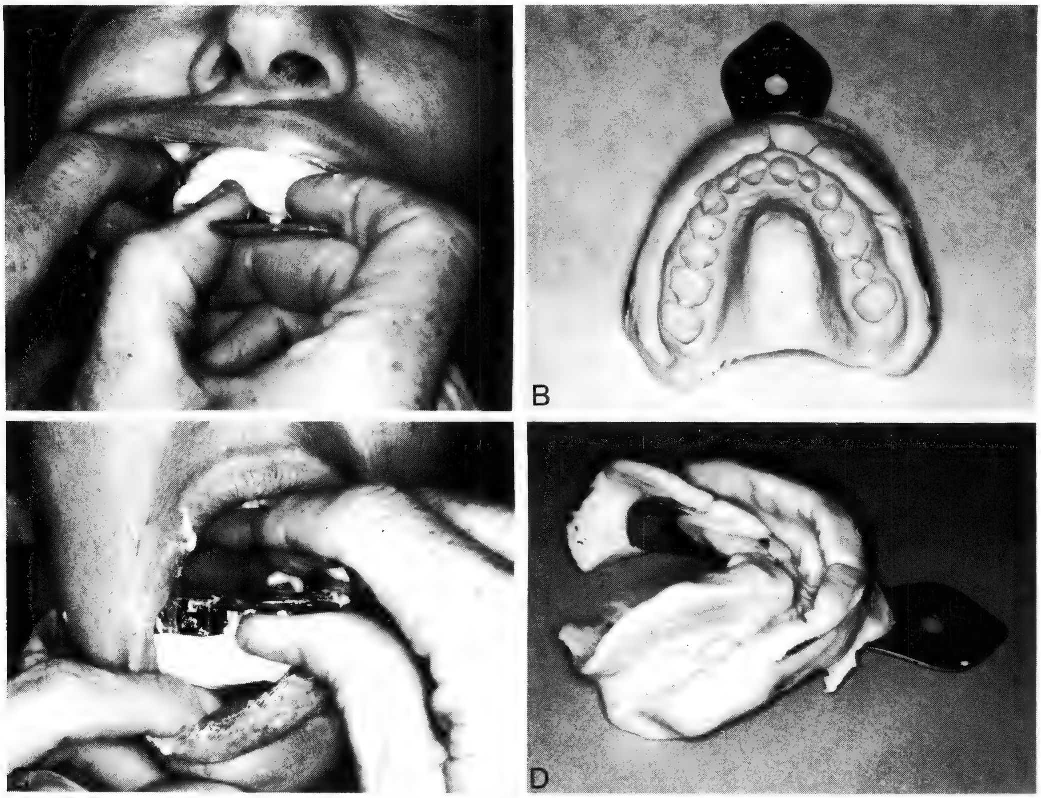


FIGURE 2–16

A, Removing maxillary impression.
B, Completed maxillary impression.
C, Removing mandibular impression.
D, Completed mandibular impression.

Consequently, the impression should not be removed from the mouth for at least two to three minutes after the gelation has occurred, which is approximately the time at which the material loses its tackiness.

Removing the Impression

The structure of the material after gelation is such that a sudden force is more successfully resisted without distortion or fracture than is a slow gradual force. For this reason, the impression should be removed rapidly with a jerk, rather than be teased out of the mouth. Removal should also be accomplished in a direction as parallel to the long axes of the teeth as possible. As a rule, pressure in an occlusal direction should be simultaneously exerted on the buccal flanges and tray handle to break the seal and free the impression from the mouth (Fig. 2–16). The impression is then washed under a forceful stream of tap water.

Pouring the Cast

Dental stone is mixed with water in proportions designated by the manufacturer. Vacuum spatulation is recommended to reduce air bubbles in the mixture. Excess surface water is removed from the impression by using compressed air. Small increments of the stone mix are placed in one end of the impression and vibrated from that end of the arch to the other. Flowing the stone mix slowly around the arch helps to avoid trapping of air bubbles. When all the surfaces have been covered with stone, the impression is overfilled (Figs. 2–17 and 2–18). It is then inverted over a mound of stone on a ceramic tile or glass surface, and the excess stone is made to conform to the border of the impression with a spatula (Fig. 2–19). The tongue area of a mandibular impression also should be cleared of excess stone using a spatula (Fig. 2–20).

The stone should set undisturbed for at least 30, or preferably 60, minutes. It is possible to allow the stone to remain in contact with the alginate for too long a time, such as overnight, so that a chalky stone surface results.

The casts are removed from the impression and trimmed on a model trimmer, with care taken not to cut away any significant anatomic landmarks, while border areas are removed that would prevent occluding the casts (Fig. 2–21).

The teeth and all other working areas on the diagnostic casts must be completely free of voids, nodules, or other false contours. Their form allows for an accurate survey analysis to determine the path of insertion for restorations and prostheses, which will provide the best esthetic results while conserving the greatest amount of tooth structure.

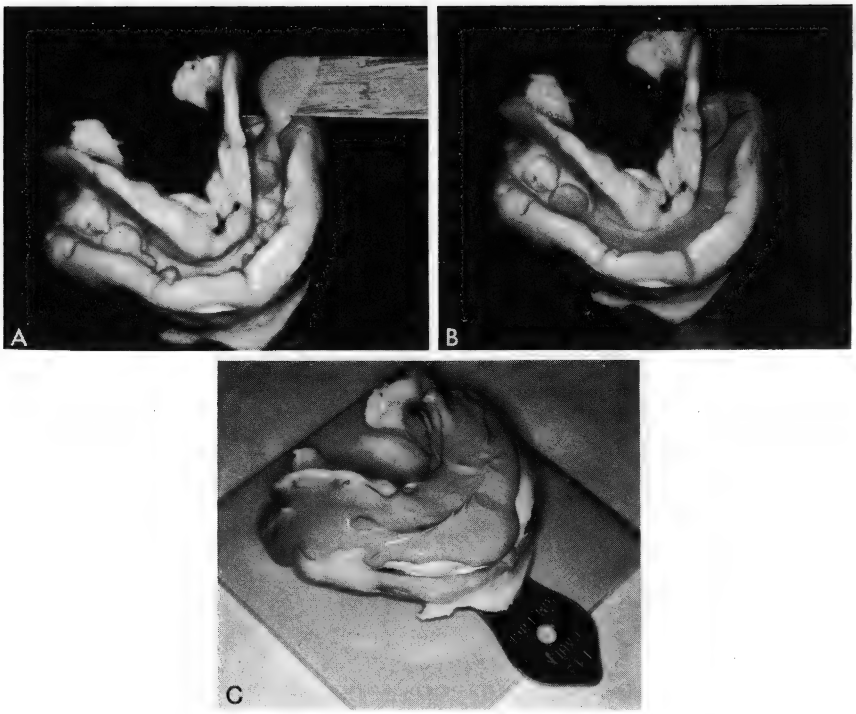


FIGURE 2–17

A, Adding small amount of stone mix to posterior area of mandibular impression while tray contacts vibrator.
B, Vibrating stone mix around arch.
C, Impression filled and ready for base.

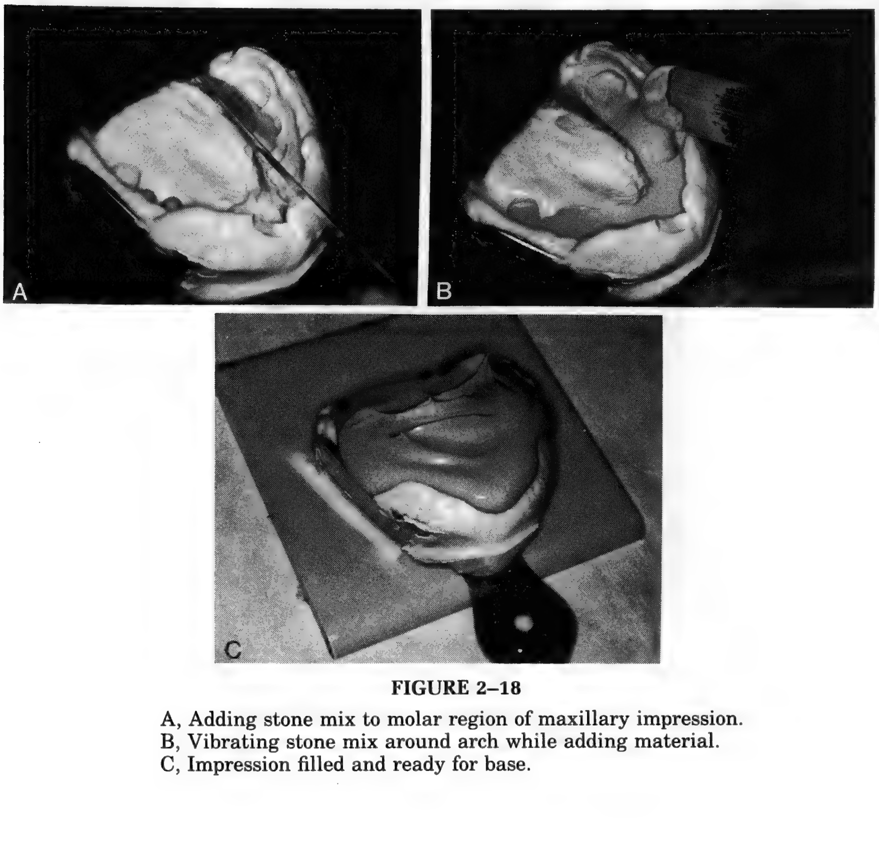


FIGURE 2–18

A, Adding stone mix to molar region of maxillary impression.
B, Vibrating stone mix around arch while adding material.
C, Impression filled and ready for base.

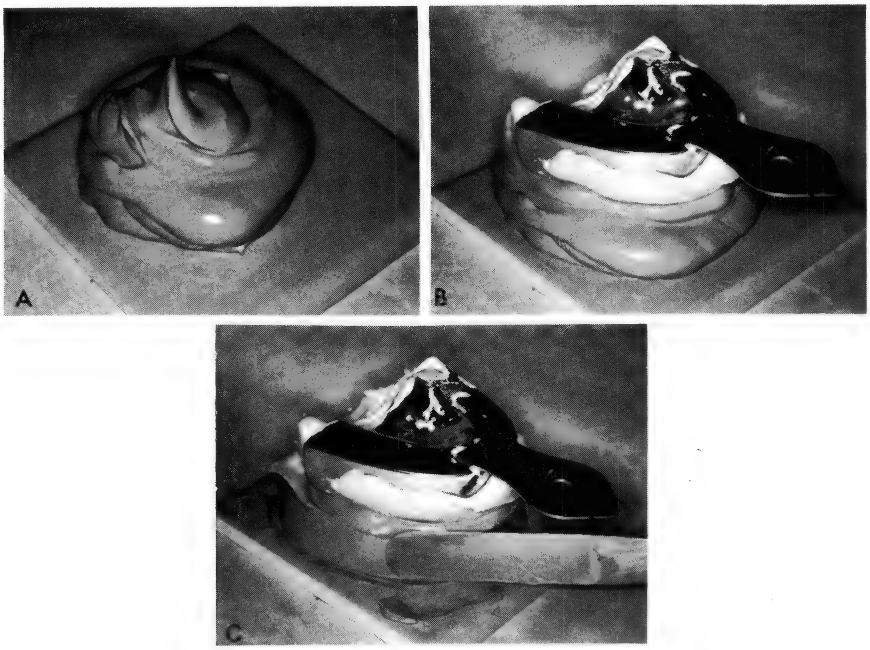


FIGURE 2–19

A, Stone mix for base placed on ceramic tile.
B, Poured maxillary impression inverted onto base.
C, Shaping base of cast with spatula.

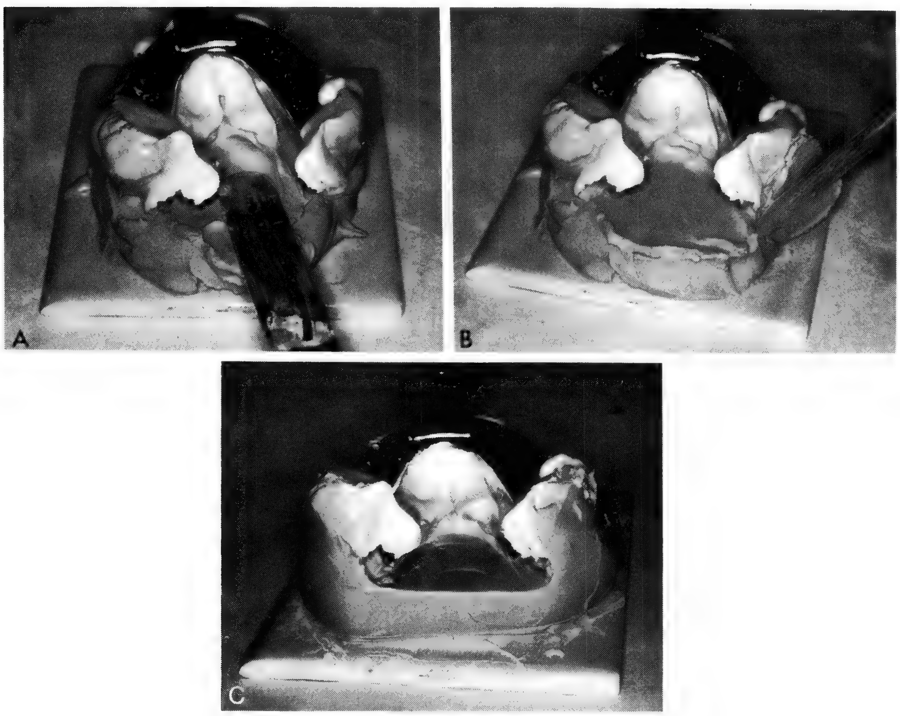


FIGURE 2–20

A, Mandibular impression inverted on base. A spatula is being used to clear excess stone from the tongue space.
B, Placing additional stone at the retromolar pad area of the impression.
C, Stone has hardened.

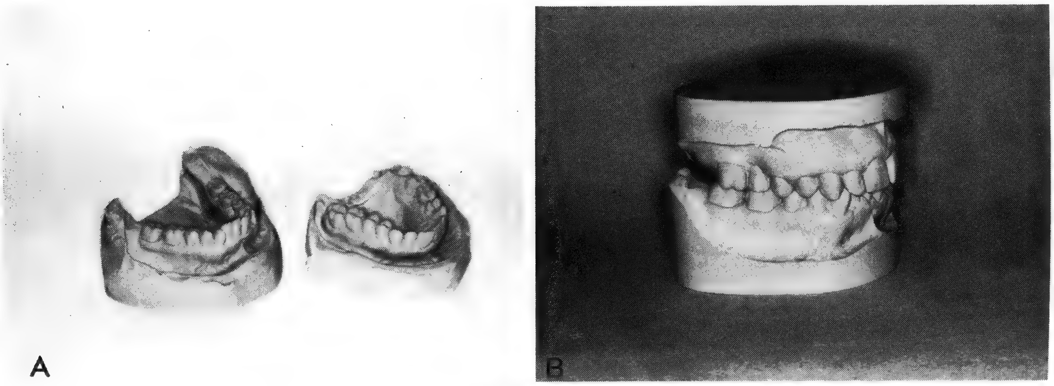


FIGURE 2–21
A, Separated casts before trimming.
B, Trimmed cast.

SURVEY ANALYSIS

The path of insertion is the line or direction in which the prosthesis will be simultaneously seated on all the prepared abutment teeth. The best path of insertion is determined on the diagnostic casts by using an analyzing rod in the dental surveyor to check the long-axis relationship of the crowns (Fig. 2–22). The use of a dental surveyor is discussed in Chapter 30.

The path of insertion should assume a direction most compatible with the long axes of all the abutment teeth and one that requires the least amount of reduction from the surfaces to be included in the preparations (Fig. 2–23). When abutment teeth are malaligned, portions of the crowns that interfere with the path of insertion can be identified, indicating the amount of tooth reduction required to prepare the teeth so they are compatible with the path of insertion (Fig. 2–24). In esthetically critical situations, in which additional reduction is necessary to create space for an adequate thickness of ceramic material, the feasibility of such reduction can also be ascertained.

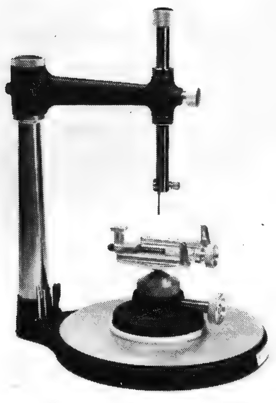


FIGURE 2–22 The Ney dental surveyor with analyzing rod clamped onto vertical spindle.

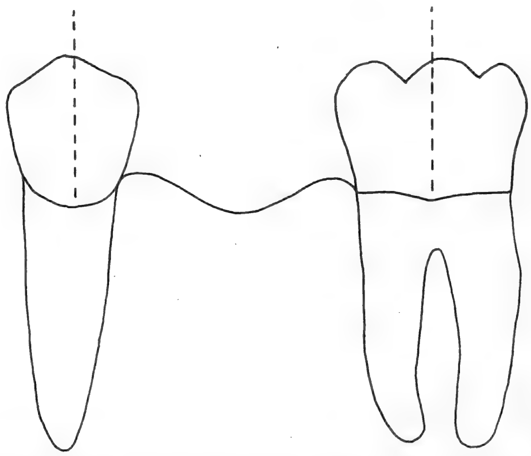


FIGURE 2–23 A path of insertion (indicated by broken lines) has been selected that is approximately parallel with the long axes of the teeth.

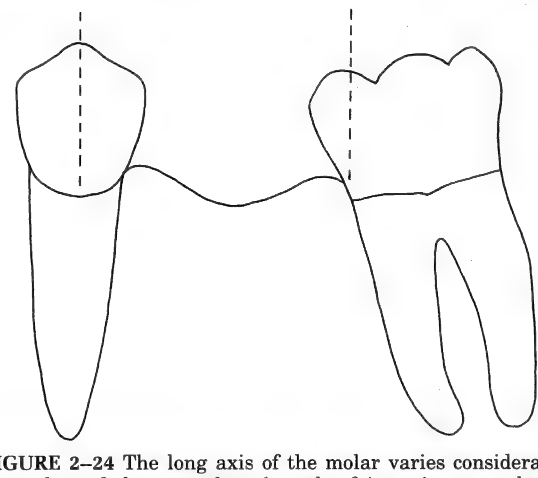


FIGURE 2–24 The long axis of the molar varies considerably from that of the premolar. A path of insertion was chosen (indicated by broken lines) that favored the premolar, since it is the smaller tooth. The molar will be reduced so it is compatible with the path of insertion. This will require greater reduction of the mesial surface.

3

Principles of Tooth Preparation

After the treatment plan has been determined, the abutment teeth must be prepared so they will accept a fixed prosthesis. Successful completion of this reduction process requires that certain mechanical, biologic, and esthetic principles be followed.

MECHANICAL PRINCIPLES

Types of Occlusal Forces

It is important to understand the types of forces commonly present in the mouth and to study those aspects of preparation form and prosthesis design that allow restorations to possess adequate retention and resistance form and thereby to resist these forces. Only then can the most appropriate mechanical design principles be developed and applied.

Three types of forces can be directed against a prosthesis during function: tipping forces (Fig. 3–1), twisting or rotational forces (Fig. 3–2), and path-of-insertion forces (Fig. 3–3).

Tipping can occur in buccolingual or mesiodistal directions, depending on the point and direction of force application. Twisting or rotational forces may cause a restoration to start to move circumferentially around the prepared tooth. As an example, if a facially directed force is applied to only one retainer, the periodontal ligament permits some facial movement of that abutment tooth, producing rotational forces on the retainers. Path-of-insertion forces can be apically or occlusally directed, depending on whether the mandible is closing into a bolus of food or opening with sticky food interposed between the prosthesis and opposing teeth.

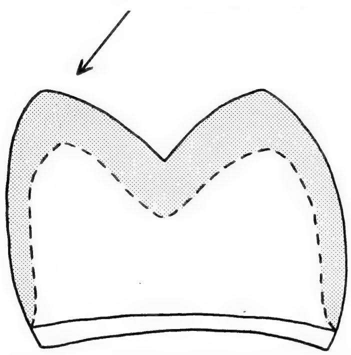


FIGURE 3–1 The type of force that tends to tip a restoration off the prepared tooth.

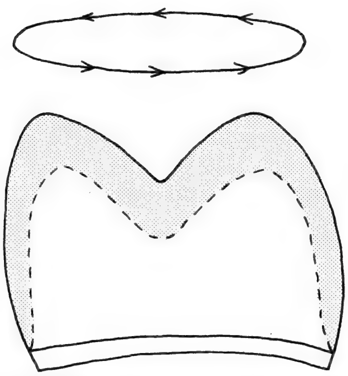


FIGURE 3–2 The type of force that tends to twist or rotate the restoration off the prepared tooth.

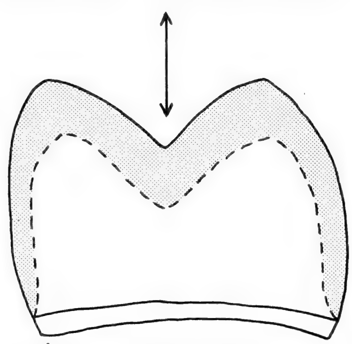


FIGURE 3–3 The type of force that tends to dislodge the restoration along the path of insertion.

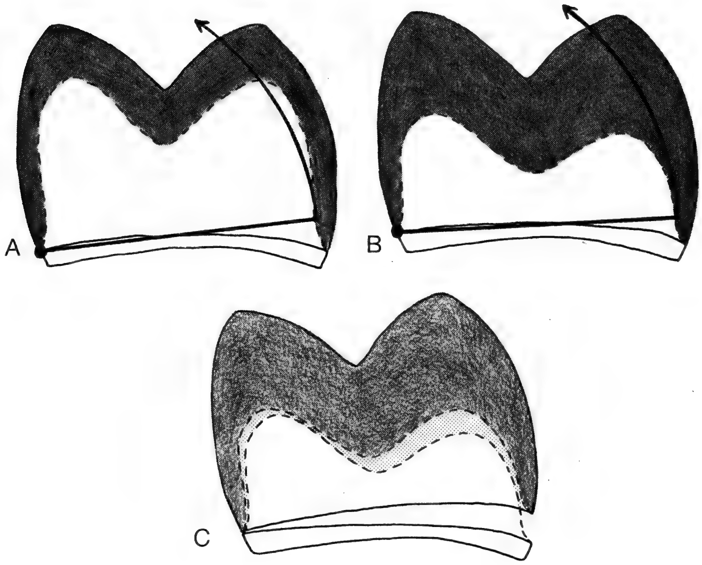


FIGURE 3–4

A, A preparation of adequate height in which tooth structure interferes with arc of rotation.
B, A short preparation providing no interference with arc of rotation.
C, Casting being dislodged from short preparation.

Factors Preventing Restoration Dislodgement

Axial Wall Height

An abutment tooth must be prepared so the retainer covers an adequate amount of occlusocervical crown dimension (axial wall height). The height required for a particular clinical situation depends on several different factors, such as the magnitude of the occluding force, the span length, the type of preparation (full or partial coverage), the length of the lever arm, and the bone support. However, the minimal acceptable height is that which allows tooth structure to interfere with the arc of rotation as tipping forces attempt to cause rotation around a fulcrum located at the finish line on the opposite side of the tooth (Fig. 3–4). On short teeth adequate axial wall height may only be achieved by extending the finish line subgingivally or onto the root surface, which otherwise would not be considered desirable or advantageous. The only other alternative is to prepare the tooth with less taper.

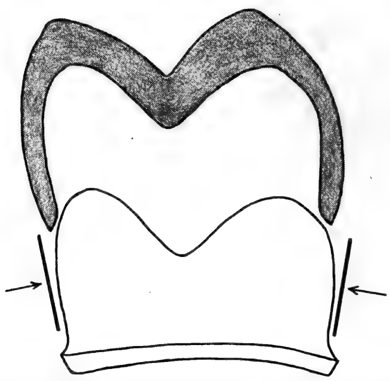


FIGURE 3–5 Rigid casting cannot be seated, owing to divergent axial walls.

Taper of the Preparation

As a tooth is prepared, opposing walls must converge occlusally, since divergent walls create undercuts and prevent a restoration from seating (Fig. 3–5).

Increased taper reduces the ability of a restoration to resist occlusally directed dislodging forces and also lessens its ability to interfere with the arc of rotation as tipping forces act to unseat the restoration (Fig. 3–6). A

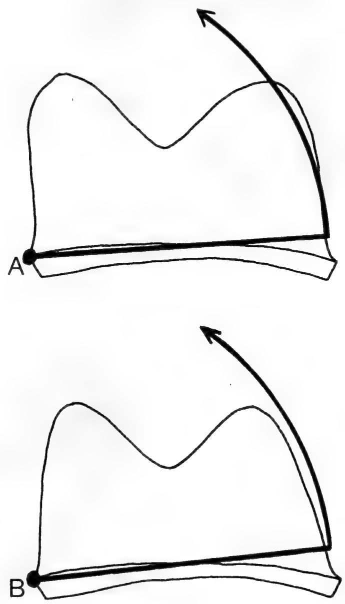


FIGURE 3–6

A, Preparation taper allowing tooth to interfere with arc of rotation.
B, Overtapered preparation providing no interference with arc of rotation.

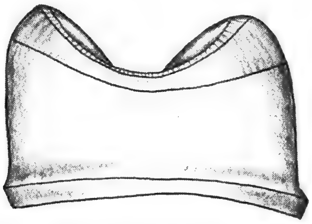


FIGURE 3–7 Mandibular molar full veneer crown preparation with ideal taper as viewed mesially.

total convergence of 3 to 5 degrees is considered to be ideal and satisfies the requirements of retention and resistance (Fig. 3–7).

Instruments are available to insure proper paralleling of preparations and produce an ideal convergence for each abutment. One of the most recent to appear makes use of precision parts that attach a high-speed handpiece to the dental arch while allowing freedom of movement of the handpiece (Fig. 3–8).*

When the unprepared tooth possesses excessive crown taper, additional length must be achieved to help compensate for this defect. Conversely, short teeth must be prepared with a minimal amount of taper.

*Parallel-O-Prep, C. D. Charles, Inc., Chicago, IL 60606.

Ratio of Preparation Diameter to Axial Wall Height

It is often mistakenly assumed that a large-diameter tooth such as a mandibular molar will yield a more retentive preparation than, for example, a mandibular premolar. However, if the axial wall height and taper are the same for both teeth, the smaller-diameter tooth (premolar) interferes more effectively with the arc of rotation because the smaller radius of curvature allows the preparation to better resist dislodgment (Fig. 3–9).

Circumferential Irregularity

The circumference of a tooth is usually irregular in form, and when the tooth is uniformly reduced an irregular shape is formed, which enhances the ability of a restoration to resist both tipping and twisting forces (Fig. 3–10). When a tooth is encountered that is round, short, or overtapered, intentionally formed irregularities such as boxes or grooves may be used to produce areas that interfere with dislodgment of the restoration and therefore increase both retention and resistance form (Fig. 3–11). Boxes are more effective than grooves; therefore they should be used when sufficient tooth structure is available.

The best location for placing a box or groove in a full veneer abutment preparation is in the middle of a proximal surface where it adds resistance to faciolingual dislodging forces. Since the distance between the finish line fulcrum point and the box or groove is shorter than the distance across the entire preparation, a shorter

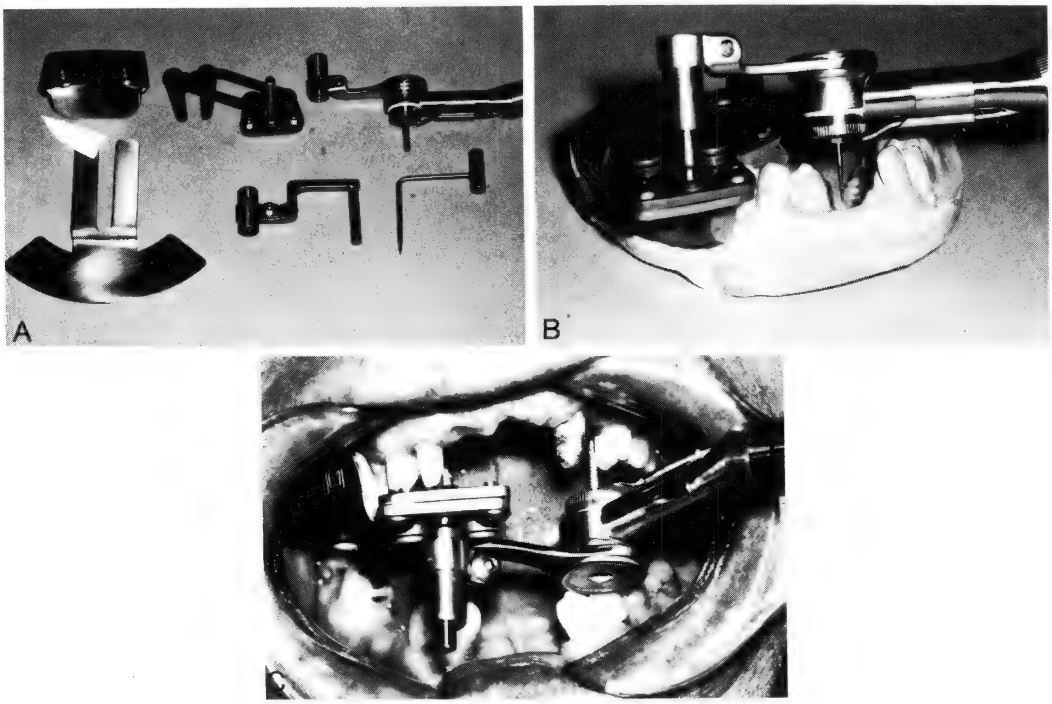


FIGURE 3–8 Paralleling Device

A, Components of Charles paralleling instrument.
B, Preclinical setup of instrument on diagnostic cast using metal base adapted to teeth with stiff impression material.
C, Instrument attached to maxillary arch for preparation of long-span multiple abutment prosthesis.

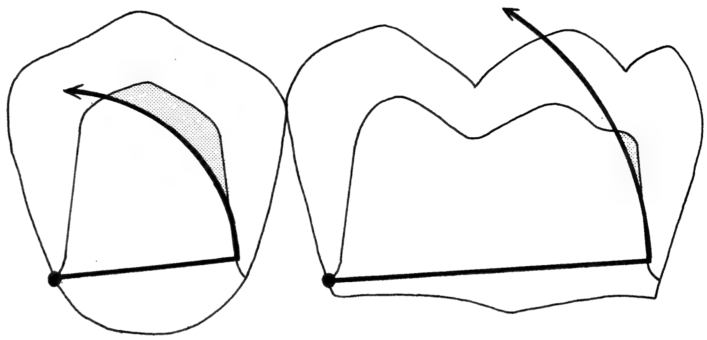


FIGURE 3–9 Full veneer preparations of approximately the same height and taper completed on mandibular premolar and molar illustrate the better resistance to mesiodistal tipping inherent in the smaller-diameter tooth.

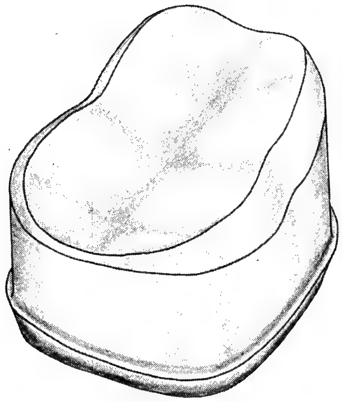


FIGURE 3–10 The form of the mandibular molar often yields a somewhat rectangular preparation when the tooth is uniformly reduced following existing contours. Note the slight depressions in the center of facial and lingual surfaces in which developmental grooves were present. Rectangular form and circumferential depressions aid resistance to dislodgment as forces attempt to rotate or tip the restoration.

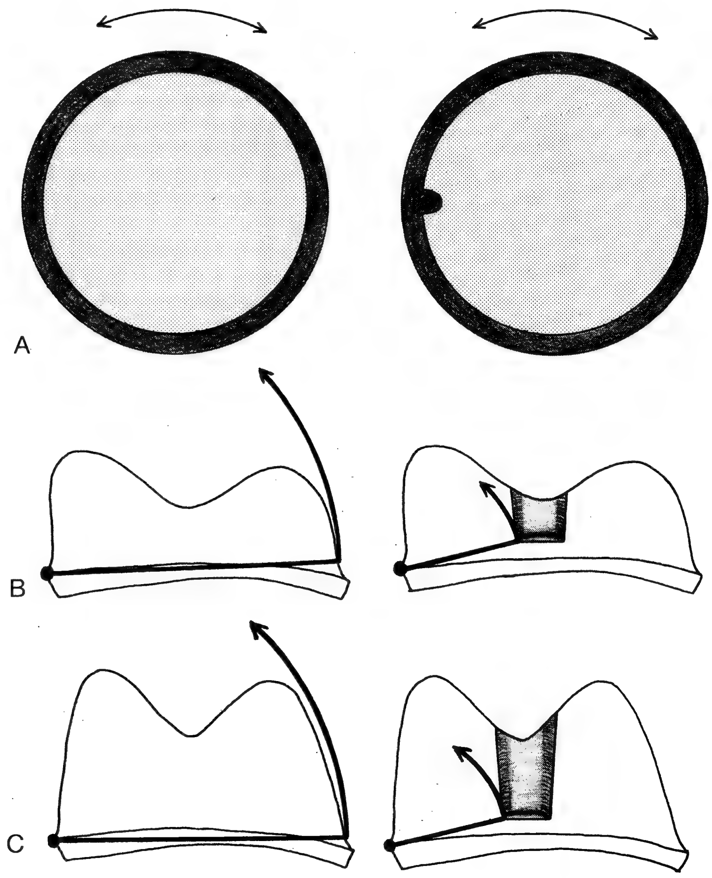


FIGURE 3–11

A, The circular preparation on the left allows casting to be easily rotated around the tooth. A circumferential irregularity (groove) has been placed in the tooth on the right to prevent rotation of the restoration.
B, On the right, a proximal box increases resistance to tipping by producing an arc of rotation with a shorter radius.
C, The overtapered preparation on the left offers no interference to arc of rotation. On the right, a proximal box has been placed to provide tooth structure, which interferes with the arc of rotation.

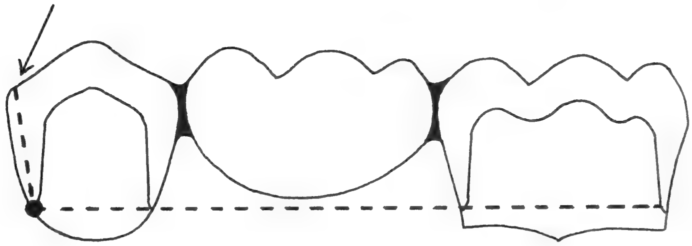


FIGURE 3–12 Force applied to the mesial marginal ridge produces a short lever that is easily resisted by the molar abutment; thus a facial or lingual groove would have little effect.

radius to the arc of rotation is formed, which allows the prepared tooth to more effectively resist forces that attempt to dislodge the prosthesis (Fig. 3–11).

A groove or box located on either the facial or lingual surface would provide additional resistance to mesiodistal forces, but in the case of a fixed prosthesis these forces are usually resisted adequately by the other abutment teeth. For example, when occlusal forces are applied to the mesial marginal ridge of the anterior retainer, the prosthesis attempts to rotate mesiodistally around the finish line of the mesial abutment, requiring extensive force to dislodge the posterior retainer because of the short anterior lever arm (Fig. 3–12).

All partial veneer crown preparations require the use of boxes or grooves, since the restoration does not encompass all of the crown and if they are not present, the crown would lack proper retention and resistance form (Fig. 3–13). A decision as to which to use must be based not only on the magnitude of the dislodging forces but also on the amount of available tooth structure. While a box is the most effective type of irregularity, it is larger than a groove and, therefore, requires a greater bulk of tooth structure than is usually present in anterior teeth and mandibular premolars. For this reason, grooves instead of boxes are usually placed in these teeth.

Occlusal Irregularity

Occlusal reduction following anatomic form produces an irregular surface that aids resistance to dislodging forces (Fig. 3–14). A flat reduction provides little interference and unnecessarily reduces the length of the preparation.

Auxiliary occlusal irregularities such as pinholes (Fig. 3–15) can be used to enhance resistance to dislodgment. On anterior teeth, which often possess short proximal and lingual walls, pinholes placed in the cingulum or lingual surface are usually required with partial veneer crown preparations to augment the retention and resistance form achieved by the grooves (Fig. 3–16). Also, conservative pinledge preparations are used on incisors with multiple pinholes being used in place of grooves (Fig. 3–17).

Rigidity

The ability of a prosthesis to resist flexure and loosening is related to its thickness.

Occlusal surfaces must be reduced a minimum of 1 to 1.5 mm to provide sufficient rigidity of the restoration, whereas an axial reduction of 0.3 to 0.5 mm cervically increasing to 1.0 mm toward the occlusal surface allows sufficient thickness peripherally. Greater reduction is needed if the casting is to be veneered with a tooth-colored ceramic material.

Adaptation

A small amount of space is required between a restoration and the prepared tooth to allow complete seating

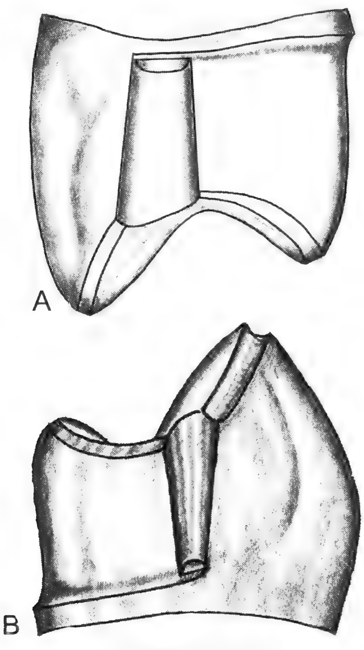


FIGURE 3–13

A, Maxillary premolar partial veneer crown preparation using proximal boxes.
B, Mandibular premolar partial veneer crown preparation using proximal grooves.

FIGURE 3–14 Anatomic reduction of mandibular molar, in which adequate occlusal irregularity was developed.

FIGURE 3–15 Lingual pinhole placed to help compensate for short lingual wall resulting from tooth fracture.

during cementation. However, excessive space reduces the resistance to dislodgment by placing too much dependence on the physical properties of the luting agent.

Surface Area

In general, when preparations of teeth are compared, those with greater coronal surface area provide more resistance to dislodgment. However, undue credence should not be placed on surface area alone, since the location of the increased surface area is more important than the actual total area. As previously discussed, some large teeth have a poor ratio between the diameter and axial wall height of the preparation and therefore are less retentive than smaller teeth although they possess considerable surface area. Increased surface area is most significant when the additional area results in greater axial wall length.

FINISH LINE REQUIREMENTS

The point at which a preparation terminates on the tooth is called the *finish line*. A finish line serves many functions. (1) During visual evaluation of the tooth preparation, it is a measure of the amount of tooth structure already removed. It also delineates the extent of the cut in an apical direction. The more distinct it is, the better it serves these purposes (Fig. 3–18). (2) The finish line is one of the features that can be used to evaluate the accuracy of the impression made for indirect procedures. (3) On the die, a distinct finish line helps in the evaluation of the quality of the die and aids in trimming it accurately. (4) The correct marginal adaptation of the wax pattern depends on an obvious finish line. (5) The evaluation of the restoration is also aided by a proper finish line. (6) At cementation, a sharp finish line aids in determining whether the restoration is fully seated.

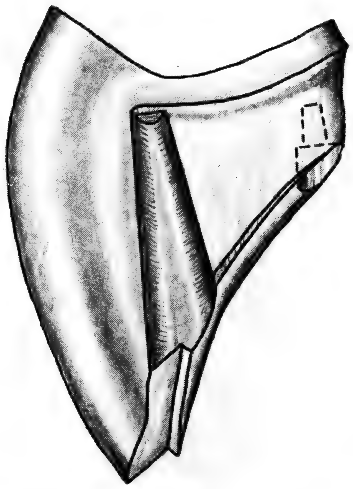


FIGURE 3–16 Cingulum pinhole placed in maxillary canine partial veneer crown preparation.

Several forms of finish lines can be developed: chamfer, knife edge or chisel edge, feather edge, shoulder, and beveled shoulder (Fig. 3–19).

A chamfer is the preferred cervical finish line for fixed prosthodontics and should be utilized whenever possible because it is easily developed and visually distinct.

The knife edge or chisel edge finish line is acceptably distinct, although it is not as well defined as the chamfer. It is most often used on tipped teeth when formation of a chamfer would result in excessive tooth reduction (Fig. 3–20).

A feather edge finish line is unacceptable because it is not sufficiently distinct and results in so little cervical tooth reduction that the restoration must be overcontoured to possess adequate rigidity. Also, since a feather edge is difficult to see visually, occlusocervical undulations and irregularities in the finish line are more likely to be present, making it much more difficult to fabricate a restoration that fits accurately.

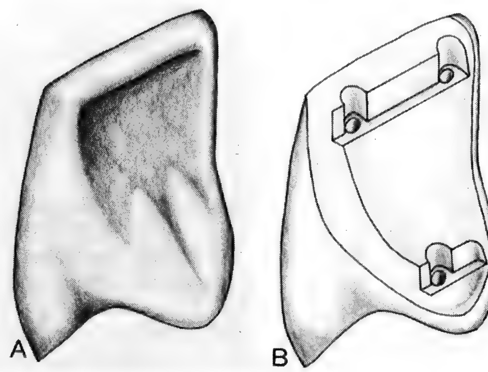


FIGURE 3–17

A, Unprepared maxillary central incisor.
B, Pinledge preparation utilizing three pinholes.

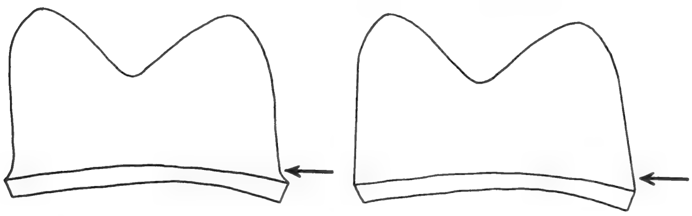


FIGURE 3–18 The tooth on the left possesses an adequately distinct finish line; the tooth on the right does not.

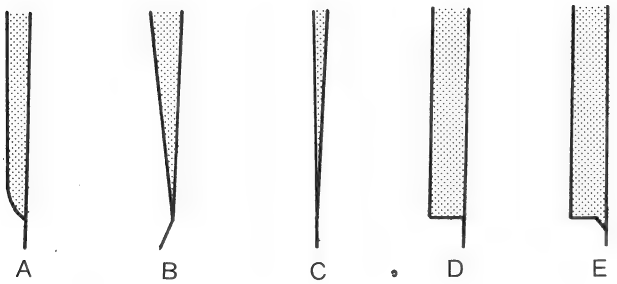


FIGURE 3–19 The five types of finish lines: (a) chamfer, (b) knife edge or chisel edge, (c) feather edge, (d) shoulder, and (e) beveled shoulder.

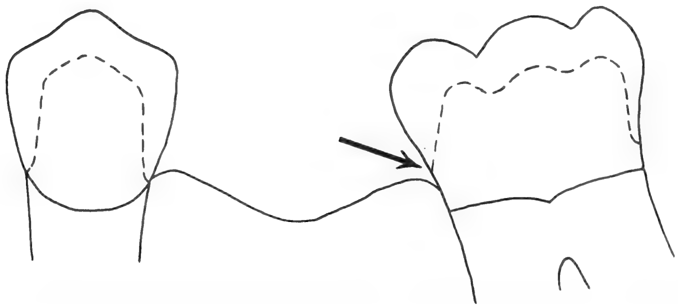


FIGURE 3–20 Use of knife edge finish line on mesial side of tipped mandibular molar to avoid pulpal proximity.

The shoulder and beveled shoulder are not advocated for routine use because they are difficult to form and produce the greatest depth of tooth reduction. However, they are required with ceramic restorations in which proper color is achievable only through material thickness. Chapter 22 contains a more detailed description of these finish lines, their proper development, and comparisons of the shoulder and beveled shoulder.

INSTRUMENTATION

Rotary instruments must be selected that allow the tooth to be reduced according to the requirements of proper retention and resistance form and finish line development. Also, instruments must be available for placement of well-defined and smooth boxes, grooves, and pinholes where these are needed.

Diamond cutting instruments that have diamond particles attached to a concentric metal shaft efficiently abrade enamel (Fig. 3–21). When the instrument contacts the tooth structure, many particles simultaneously come in contact with the surface, and there is little tendency for the instrument to jump and wander from the desired path of movement or to produce excessive vibration, which is annoying to the patient. These instruments generally are available in coarse, medium, and fine grit with a wide range of shapes and diameters. The coarse or medium grit is used for more rapid removal of tooth structure, and the fine grit is used to smooth prepared surfaces (Fig. 3–22). A fine grit diamond instrument leaves the tooth and finish line adequately smooth for all procedures related to fixed prosthodontics.

Diamond instruments are available that have tapered walls that create the proper degree of occlusal convergence when they are held parallel to the path of insertion and moved around the perimeter of the tooth (Fig. 3–21).

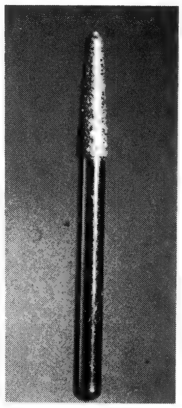
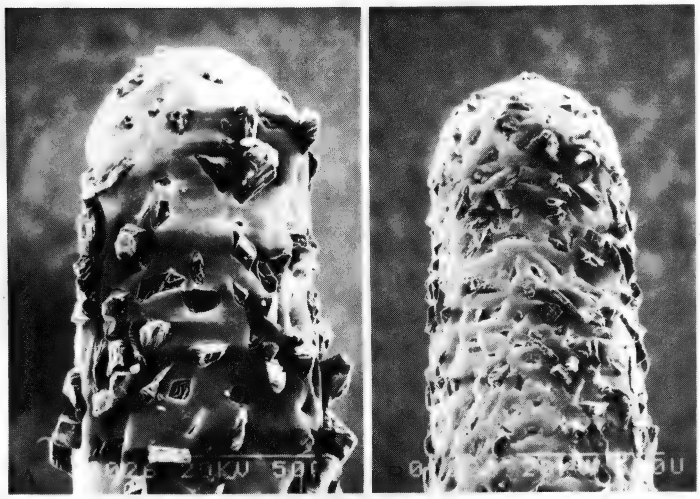


FIGURE 3–21 Tapered round-end diamond instruments manufactured with proper degree of taper.

FIGURE 3–22

A, Scanning electron microscope view of tapered round-end diamond instrument tip (medium grit).
B, Scanning electron microscope view of tapered round-end diamond instrument tip (fine grit).



A tapered round-end diamond instrument forms not only the proper preparation taper but also establishes a cervical chamfer when the tooth is reduced until the instrument tip penetrates into the tooth a distance equal to one-half its diameter (Fig. 3–23). This instrument is the one best suited for preparations requiring a chamfer finish line.

Dental burs, which possess carbide cutting blades, also effectively remove tooth structure. Plain fissure burs produce smoother surfaces than those with a crosscut design (Fig. 3–24). Burs are more often used instead of diamond instruments for beveling (Fig. 3–25A), placing boxes, grooves, and pinholes, and smoothing the facial surface and shoulder finish line on ceramic preparations (Fig. 3–25B). Grooves are commonly placed using a tapered fissure bur with a square end such as a number 169 or 170 (Fig. 3–25C, D). Boxes are better placed with straight fissure burs that are parallel-walled (such as the number 56) (Fig. 3–25E, F, G). Pinholes should first be drilled to the required depth using a number ½ round bur for its end-cutting ability and then refined to the final tapered form using a tapered fissure bur (Fig. 3–25H).

Burs, when used for bulk reduction around the circumference of a tooth, are more difficult to control than a diamond instrument. They tend to wander more frequently from the desired pathway, leaving undulations in the finish line and tooth surface. This is particularly troublesome to the novice.

Mounted abrasive stones (Fig. 3–26) are used to smooth prepared surfaces but are not suited for bulk reduction because the reduction is too time-consuming

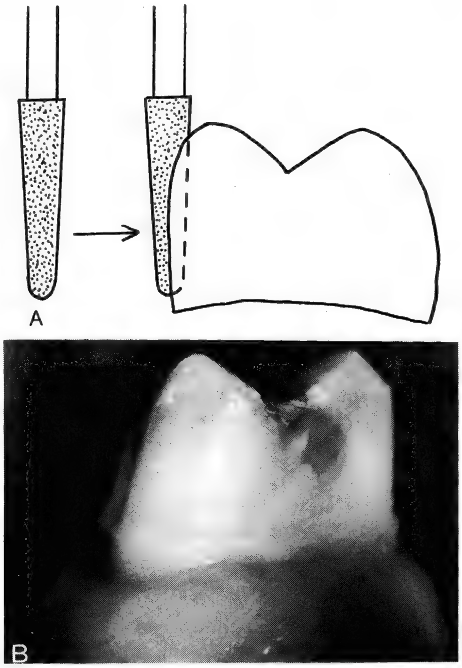


FIGURE 3–23

A, Chamfer is formed by allowing the round-end instrument to penetrate into the tooth a depth equal to one-half of its tip diameter.
B, Clinical example of chamfer finish line.

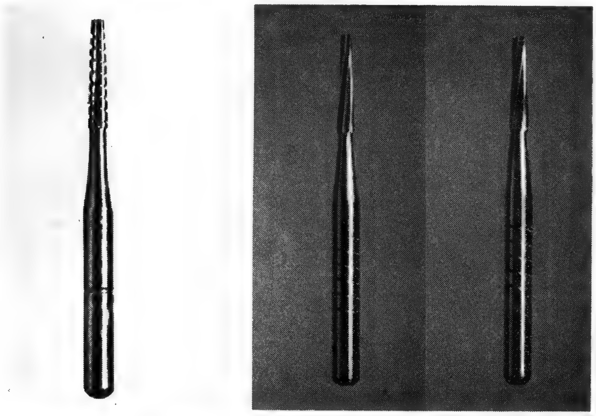


FIGURE 3–24 Tapered fissure carbide burs, left to right: number 700 (note crosscuts), number 169L, and number 170L (note absence of crosscuts).

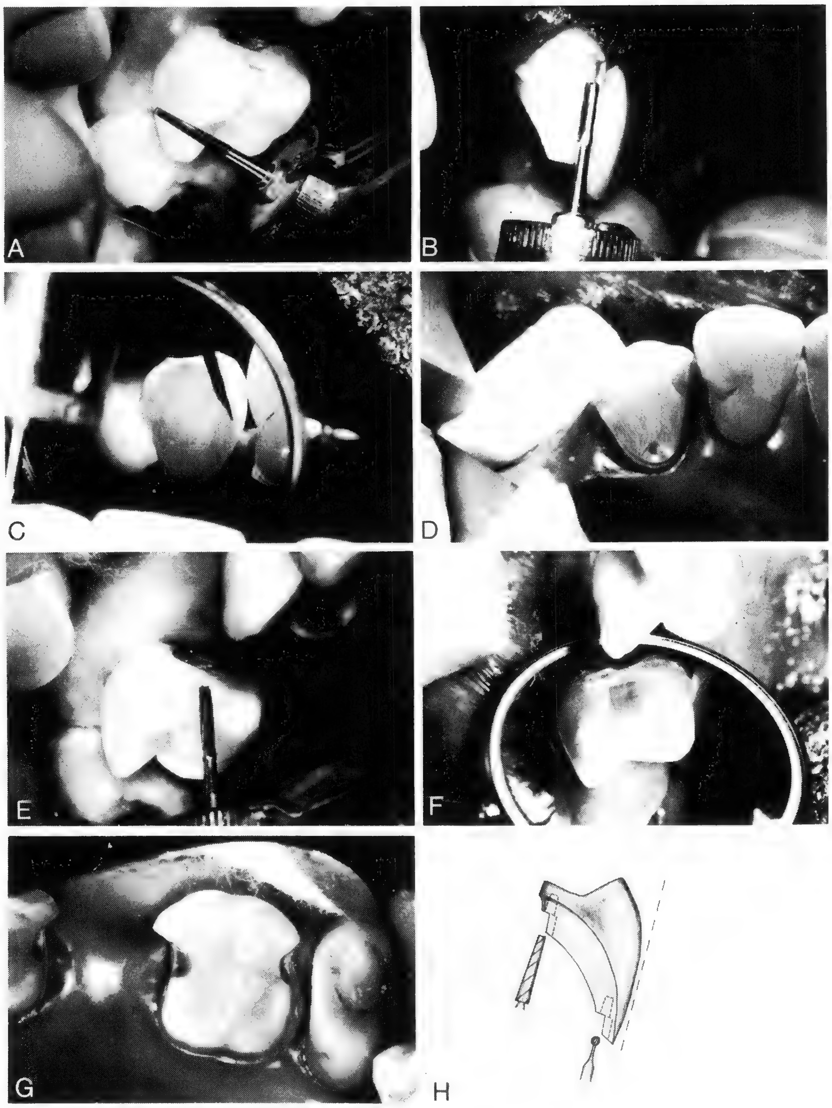


FIGURE 3–25

A, Tapered carbide bur (number 169L) being used to bevel facial cusp of maxillary molar partial veneer crown preparation.
B, Parallel walled carbide bur without crosscuts (number 56L) being used to smooth facial surface of metal-ceramic preparation on maxillary central incisor.
C, Tapered carbide bur (number 170L) being used to form proximal groove in partial veneer crown preparation.
D, Grooves formed.
E, Straight fissure bur.
F, Box formed in distal side of maxillary premolar.
G, Occlusal view of boxes formed in maxillary molar partial veneer crown preparation.
H, Pinholes formed in pinledge preparation using number ½ round bur to establish depth; form was developed using a number 700 bur.

and causes excessive heat generation. These instruments are commonly made of either aluminum oxide or silicon carbide. They produce smooth surfaces, are easily controlled, and can be altered from their manufactured shape to meet specific needs by grinding against a diamond disc.

Abrasive discs can also be used to refine and smooth a preparation (Fig. 3–26). When used intraorally, they last much longer when they are made of a waterproof material such as plastic.

Proper tooth reduction requires complete control of all rotary instruments. While controllability is aided by altering the speed of the rotation of the instrument, it is more dependent on maintaining a good grasp on the

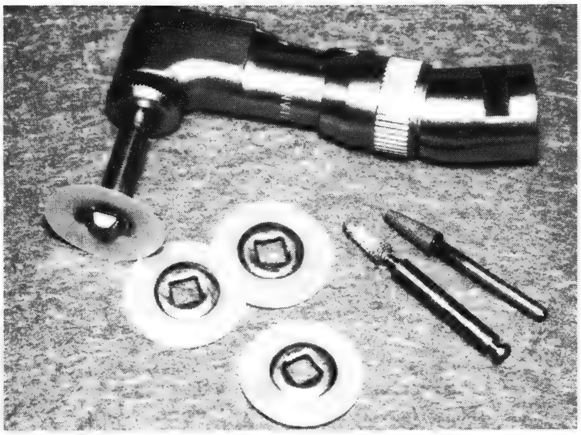


FIGURE 3–26 Abrasive stones and plastic discs used to smooth preparations.

handpiece while the hand rests firmly on other teeth in the arch (Fig. 3–27).

Visibility and Evaluation

Achieving an optimal tooth preparation requires good visual access. The use of fiberoptic handpiece lights (Fig. 3–28) and numerous lights aimed at the oral cavity from different directions greatly aids in visibility (Fig. 3–29). Also, an assistant who can skillfully remove excess oral fluids, retract soft tissue that interferes with vision, and adjust the operatory light for changing viewing conditions greatly enhances the ability to prepare teeth properly (Fig. 3–30).

While some areas of a prepared tooth can be viewed directly, indirect vision in a mirror is often the only means of assessing whether the desired tooth reduction has been achieved. The preparation taper of individual abutment teeth, and their relationship to other abutment teeth and the path of insertion, frequently can only be assessed by looking in a mirror. The use of larger mirrors allows all abutment teeth to be viewed simultaneously and is more reliable than the attempt

FIGURE 3–27 Grasp on handpiece supported by finger rest on canine to aid control of the instrument.

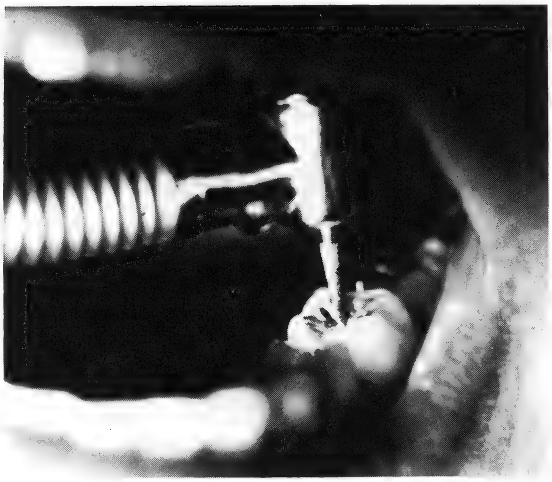


FIGURE 3–28 Fiberoptic handpiece light aiding intraoral visibility.

to move a small mirror from one tooth to another while maintaining the proper hand alignment relative to the path of insertion (Fig. 3–31). Front surface photographic mirrors are available in sizes that permit viewing one-half or all of an arch simultaneously.

When using a mirror, the examiner must frequently evaluate preparation taper by only an occlusal view. It must be remembered that when two axial walls are closer together than the examiner's eyes, a slight amount of occlusal divergence could be visually undetected if both eyes are used to view the tooth. The use of only one eye can help overcome this problem but can lead to greater than normal taper if the two walls being evaluated are widely separated. In the final analysis, it is only through experience with varying degrees of

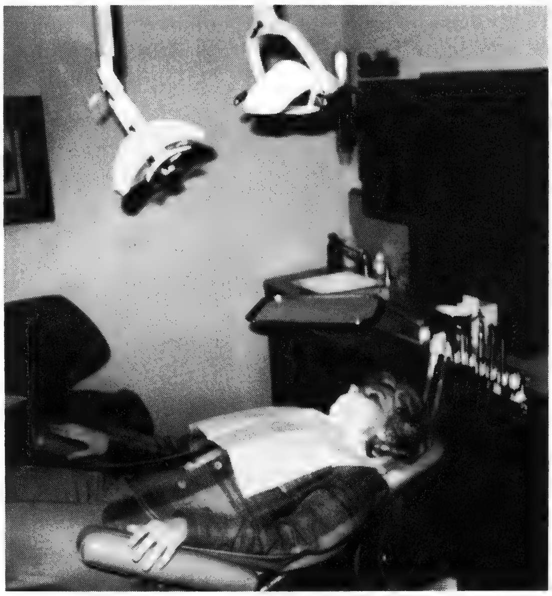


FIGURE 3–29 Dual overhead lights providing illumination from different angles.

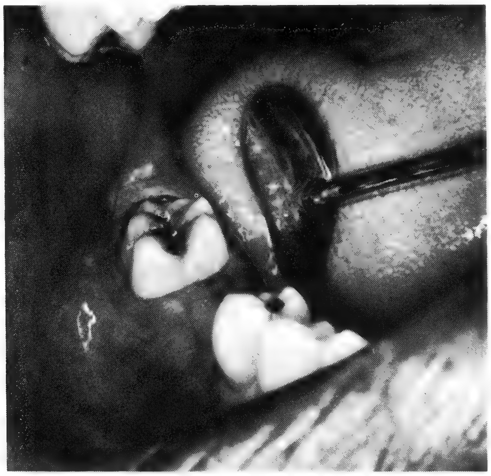


FIGURE 3–30 Dental assistant retracting patient's tongue to improve operator's visibility.

occlusal convergence that an accurate evaluation of taper can be visually made either by direct vision or by using a mirror. Some guidelines, however, can be useful while the examiner is gaining experience. If the finish line and axial walls are visible from an occlusal view when only one eye is used, there is little chance that occlusal divergence (an undercut) is present. Also, a straight periodontal probe can be used as an analyzing tool. While the examiner maintains a good finger rest, the probe can be moved from intimate contact with one opposing wall to the other to help evaluate the amount of taper.

BIOLOGIC PRINCIPLES

Pulpal Considerations

Teeth must be prepared in a manner that creates the least amount of trauma to the pulp. Retaining as much tooth structure as possible aids in achieving this goal, as does control over the depth and speed of reduction. Also, the proper use of rotary instruments and the application of surface coolants help to reduce pulpal injury.

FIGURE 3–31 Large round mirror that allows simultaneous viewing of both abutment teeth.

Conservation of Tooth Structure

The use of partial coverage preparations, when possible, is one of the best means of conserving tooth structure and usually causes less pulp damage. Conservation, however, can be exercised by retaining as much tooth structure as practicable for full-coverage restorations as well.

Depth of Reduction

Controlling the amount of tooth reduction is necessary if excessive taper or pulpal injury is to be avoided while space is provided for an adequate amount of restorative material. Proper control is best provided by placing strategically located depth cuts in the unprepared tooth surfaces. These cuts are placed to the desired depth, and then intervening tooth structure is removed by using the base of the depth cut as a guide to proper reduction (Fig. 3–32).

When a preparation becomes excessively deep, owing to removal of caries or other reasons, an insulating base material should be placed over the area in proximity to the pulp. A minimal base thickness of approximately 0.5 mm is required to achieve adequate protection against thermal shock.

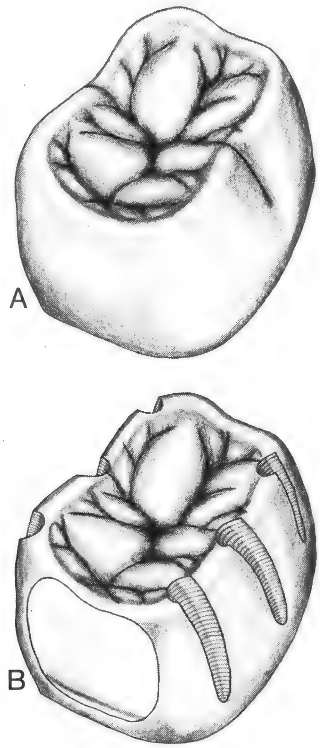


FIGURE 3–32

A, Mandibular second molar prior to reduction.
B, Facial and lingual depth cuts placed to provide uniform depth of reduction.

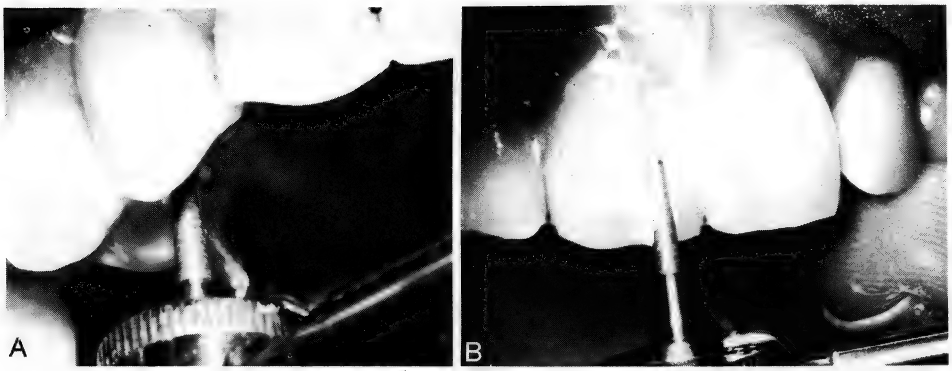


FIGURE 3–33
A, Handpiece delivering a water stream.
B, Handpiece delivering a water spray.

Speed of Reduction

Rapid continuous removal of tooth structure causes rapid heat buildup with a greater potential for irreversible pulpitis. Reduction should be performed intermittently in a steady controlled manner. Reducing the tooth for a period of five to ten seconds and then removing the instrument from the surface for a few seconds is helpful in avoiding excessive heat buildup.

Instrument Age and Use of Pressure

Only sharp instruments should be used for bulk tooth reduction, since dull ones create more friction and thus more heat. A worn diamond instrument or partially dull bur may be advantageous to smooth a preparation but should not be used to remove significant amounts of tooth structure.

Rotary instruments must be held firmly against the tooth to permit a controlled removal of tooth structure. However, use of excessive pressure for rapid reduction should be avoided, since this causes undue heat generation. This problem is accentuated if partially worn instruments are used.

Use of Coolants

Application of a coolant to the surface of a material as it is shaped has long been used to reduce heat buildup, and this procedure is most beneficial during tooth preparation.

Handpieces can deliver a water stream (Fig. 3–33A), water spray (Fig. 3–33B), or air to the rotary instrument and tooth surface during reduction. A water stream is the most effective means of cooling, followed by a water spray, and then air. In order to minimize pulpal trauma and postoperative discomfort, the authors of this text recommend that a water stream or spray be used for all bulk tooth structure removal during fixed prosthodontic preparations.

A disadvantage of water is that it interferes with vision and is therefore not well suited for cooling a tooth during refinement, smoothing, and the placement of the intricate details required with certain preparation designs. However, these aspects of a preparation can be safely accomplished using only air and intermittent tooth contact, since smaller amounts of tooth structure are being removed.

PERIODONTAL CONSIDERATIONS

A supragingival location for the finish line is preferred whenever possible (Fig. 3–34). This location allows good visual access for evaluating finish line form, facilitates an accurate impression of the prepared tooth, allows

FIGURE 3–34 A supragingival finish line.

FIGURE 3–35 A short tooth requiring a subgingival finish line to gain retentive length and improve the esthetic result.

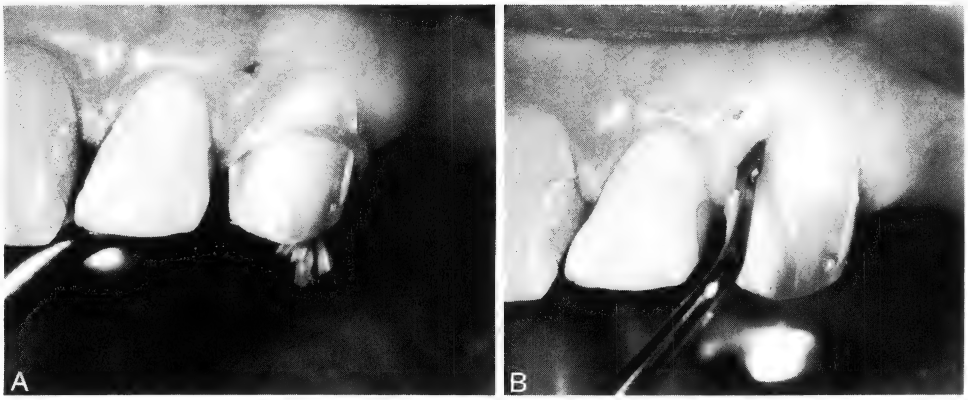


FIGURE 3–36
A, Retraction cord looped around partially prepared tooth.
B, Hand instrument used to place cord into sulcus and produce gingival retraction.

more accurate assessment of prosthesis fit and contour, provides access for marginal refinement and polishing, and permits more accurate long-term postinsertion evaluation of marginal integrity. However, the most important reason for using supragingival margins probably relates to periodontal health. There is no junction of any restorative material and the tooth that is as smooth as intact tooth structure. Consequently, some marginal plaque accumulation is inevitable, and when this occurs subgingivally, it is more difficult for the patient to remove so that the likelihood of adverse periodontal changes increases.

Despite the disadvantages, certain tooth preparations must be extended cervically to the gingiva in order to remove caries, cover existing restorations, gain adequate length to the preparation, or achieve a more esthetic result when placing ceramic restorations (Fig. 3–35).

Special care must be exercised when a subgingival margin is necessary to avoid excessive soft tissue trauma from rotary instrumentation. The gingiva must be carefully held out of contact with diamonds or burs by placing a retraction cord in the gingival sulcus (Fig. 3–36), by holding the tissue back with a hand instrument (Fig. 3–37), or by both. While these procedures induce some trauma, it is less than that caused by rotary instruments cutting the soft tissue. These instruments can rapidly remove soft tissue, dramatically altering its form or obliterating it. Subsequent healing often does not return the tissue to its normal occlusocervical position or form (Fig. 3–38). These changes can create difficulty in maintaining good oral hygiene and also can cause esthetic problems. More information relative to proper soft tissue management during clinical procedures is presented in Chapters 10 and 25.

Partial-coverage restorations generally promote healthier gingival tissue than do full-coverage restorations. This response is related to the fact that less of the finish line approximates the gingiva, particularly facially, where the tissue appears to be more susceptible to change when it is contacting a restorative material.

ESTHETIC PRINCIPLES

Esthetic requirements continue to increase the number of ceramic restorations being utilized. Achieving a color that matches the surrounding teeth necessitates a certain minimal thickness in the ceramic material, which can only be accomplished by adequate and uniform reduction of the facial surface. The use of depth cuts not only prevents excessive reduction depth, as discussed earlier, but can also insure that uniformly adequate reduction is achieved and proper restoration color achieved.

FIGURE 3–37 Hand instrument holding gingiva out of contact with rotary instrument.

FIGURE 3–38 Abnormal gingival form caused by soft tissue damage from rotary instrument.

4

The Full Veneer Crown

The full veneer crown is a restoration that covers all coronal tooth surfaces (mesial, distal, facial, lingual, and occlusal). It can be used as a single-unit restoration or as a retainer for a fixed partial denture (Figs. 4–1 and 4–2). It can be all-metal, all-ceramic, or a combination of metal and ceramic. This chapter deals with the all-metal full veneer crown. The all-ceramic and metal-ceramic crowns are discussed in Chapters 21 and 22, respectively.

ADVANTAGES

Because it completely encircles the coronal portion of the tooth, the full veneer crown affords the most effective retention and resistance form of all of the extracoronal restorations. This characteristic allows it to be used in situations in which tooth form and alignment are not ideal and when a less than perfect preparation is a likely result. Also, since this restoration covers most or all of the clinical crown, it can be used to make relatively extensive alterations in tooth form and occlusion.

DISADVANTAGES

The most obvious disadvantage of the cast full veneer crown is its lack of esthetic qualities, which tends to limit its use to areas of the mouth that are not readily seen. Another disadvantage is that the tooth preparation is extensive in nature, often involving the loss of more tooth structure than any other type of preparation. In addition, the long finishing line adjacent to or extending below the gingival crest is less conducive to an optimal gingival response than some of the more conservative preparations.

FIGURE 4–1 Five single mandibular posterior teeth restored with full veneer crowns.

FIGURE 4–2 Mandibular three-unit fixed partial denture utilizing full veneer crown retainers.

INDICATIONS

The cast full veneer crown may be indicated under the following circumstances:

1. Presence of extensive caries
2. Existing large defective restorations
3. Fracture of the tooth
4. Need to change contour, as for removable partial denture retention

If the tooth is to be used as an abutment, the following additional circumstances may indicate full coverage:

1. Abutment tooth short occlusocervically
2. Long edentulous span
3. Greater than average occlusal forces
4. Abutment tooth alignment that requires full-coverage preparation to achieve adequate retention

TOOTH PREPARATION FOR FULL VENEER METAL CROWN

If the tooth to be prepared for full coverage is to serve as an abutment tooth, a path of insertion must be determined that will provide adequate retention of the prosthesis and be biologically acceptable to the abutment teeth. The diagnostic casts should be analyzed with a dental surveyor to determine the best path of insertion and to develop a mental picture that can be used during clinical tooth reduction. Diagnostic preparation of the teeth on mounted casts is an invaluable aid to the beginning student.

Ideally all preparations should be as retentive as possible, but the full veneer crown preparation can deviate more from the ideal than can a partial veneer preparation and still provide adequate retention. For this reason, when there is a discrepancy in the path of insertion between a tooth that is to receive a partial veneer retainer and one that is to receive a full veneer retainer, it is best to alter the full veneer preparation to favor the other tooth (Fig. 4–3).

An orderly sequence of steps and predetermined goals for each step facilitate achieving the best end result in any operation. For this reason, the production of a full veneer preparation is separated into a series of sequential steps and described in that manner. Although a skilled and experienced operator mentally combines these steps and executes the tooth preparation as one continuous procedure, it is best for the novice to prepare teeth through a series of controlled orderly steps until the total picture can be mentally mastered.

Intact or minimally restored teeth can be prepared without the need for preliminary procedures aimed at making the tooth ready for reduction. Extensively damaged or carious teeth should be restored prior to tooth reduction for the full-coverage restoration, as discussed in Chapter 27.

In order to minimize pulpal trauma, all bulk tooth reduction should be accomplished using copious amounts of water spray to cool the tooth and improve cutting efficiency. Likewise, excessive trauma to soft tissue must be avoided by carefully retracting the gingiva when this is necessary to prevent inadvertent contact by rotary instruments.

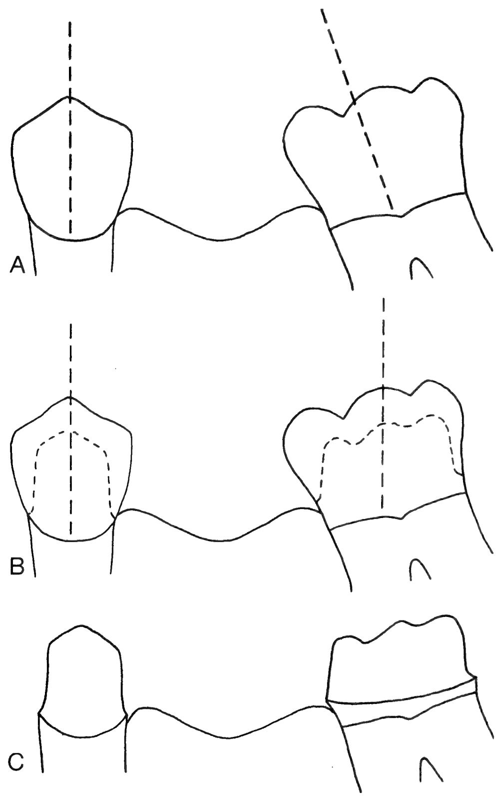


FIGURE 4–3

A, Mesially tipped molar producing malalignment with premolar.
B, Proposed path of insertion requiring more extensive preparation of molar.
C, Molar preparation altered to establish alignment with premolar.

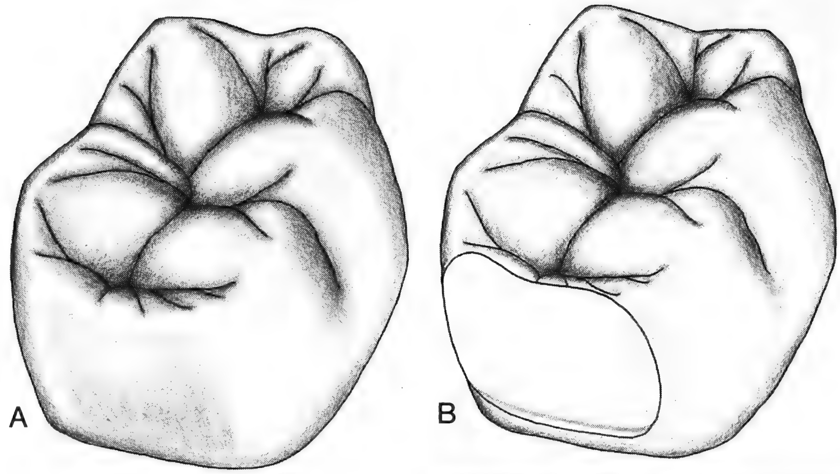
Proximal Reduction

The two proximal surfaces are reduced (Fig. 4–4) by using an appropriate coarse-* or medium-grit† tapered round-end diamond instrument in conjunction with a copious water spray. The reduction should taper occlusally 3 to 5 degrees, be compatible with the predetermined path of insertion, and terminate cervically in a chamfer 0.3 to 0.5 mm in depth. The instruments normally used have a tip diameter of 0.8 mm. However, when the proximal space is limited, a smaller instrument‡ having a tip diameter of 0.6 mm may be indicated.

The proximal reduction is extended cervically far enough to provide adequate length for retention but ideally should terminate supragingivally on enamel. When a conflict exists between the ideal point of cervical termination and the need for additional length, the length requirement must predominate, since retention is mandatory for long-term success. For adequate retention the preparation may need to be extended subgingivally, or onto the root surface, or both, as the specific situation dictates. The reduction must also extend beyond any previously placed restorative material and onto sound tooth structure, which may also necessitate a finish line that terminates on the root surface or subgingivally. When a subgingival finish line is required, a retraction cord should be placed in the gingival crevice during tooth preparation to displace the tissue and prevent laceration with rotary instruments.

Care must be exercised during the proximal reduction to avoid damaging adjacent teeth or restorations with the rotary instruments. An amalgam matrix band can be placed around adjacent teeth to help avoid abrasive contact. Should contact occur, cutting of the metal band indicates the need for realigning the instrument or the need to use a smaller-diameter instrument.

*Two Striper 767.7C, Premier Dental Products Co., Philadelphia, PA 19107.
†Blu-White 1DT, Teledyne Densco, Denver, CO 80207.
‡Blu-White 1/2 DT, Teledyne Densco, Denver, CO 80207.



PROXIMAL REDUCTION

Instrument: tapered round-end diamond
Form: tapered occlusally 3 to 5^{0}
terminates as a chamfer
Depth: 0.3 to 0.5 mm cervically
related to tooth form,
axial alignment, and
preparation length
Extension: length adequate for retention
ideally terminates on enamel
ideally terminates supragingivally

C

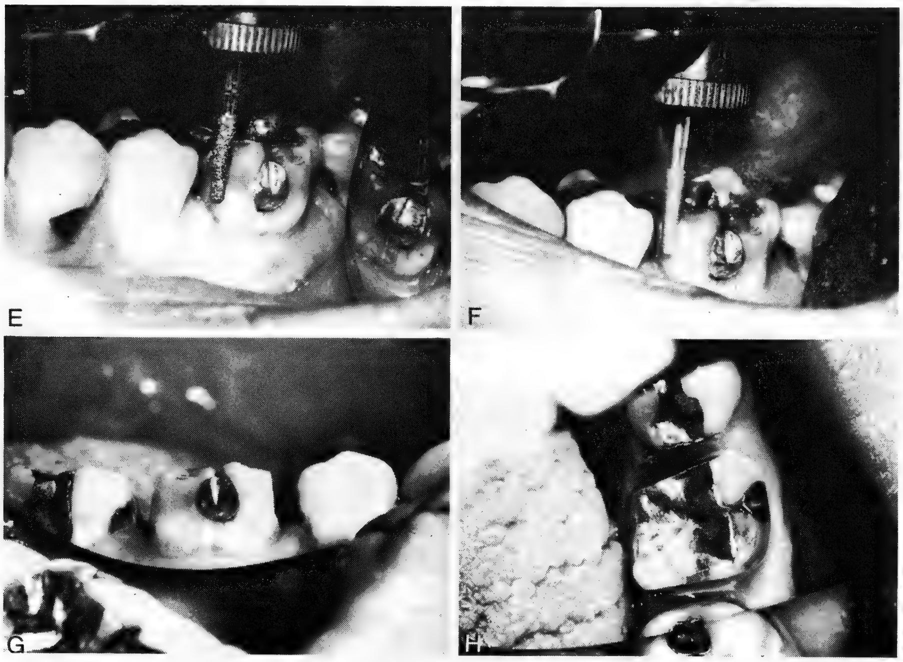


FIGURE 4–4

A, Mandibular first molar.
B, Proximal reduction.
C, Procedures for proximal reduction.
D, Facial view prior to proximal reduction.
E, Coarse-grit tapered round-end diamond instrument used for tooth reduction.
F, Water spray being used during proximal reduction.
G, Proximal surfaces reduced.
H, Occlusal view of reduced proximal surfaces.

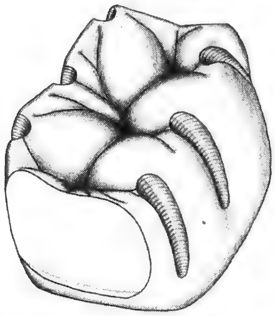
Facial and Lingual Reduction

The facial and lingual surfaces must be reduced so the casting that reestablishes tooth form will possess adequate bulk of material to properly resist occlusal forces without deformation or dislodgment. This goal is best accomplished by using facial and lingual depth cuts that follow the unprepared tooth contour (Fig. 4–5). These cuts act as guides to insure that adequate and uniform reduction is achieved.

The same tapered round-end diamond instrument is used. The depth cuts should follow the existing contour of the tooth to produce two distinctly different angulations to the occlusal and cervical aspects of each depth cut. Generally, two or three depth cuts, equally spaced along the mesiodistal dimension of the facial and lingual surfaces, provide adequate reduction guides.

The depth cuts are placed 0.7 to 1.0 mm deep in the occlusal aspect of the tooth and decrease slightly in depth cervically so as to terminate in a chamfer 0.3 to 0.5 mm in depth. Most of the retention form is achieved from the more parallel nature of the cervical aspects of the facial and lingual depth cuts, which taper 3 to 5 degrees relative to each other. The occlusal aspect of each depth cut is deeper pulpally and follows existing tooth contour, thus creating considerable taper relative to the path of insertion.

The cervical portion of each depth cut is accomplished first and extended cervically far enough to achieve adequate length for retention. As stated before, the cut

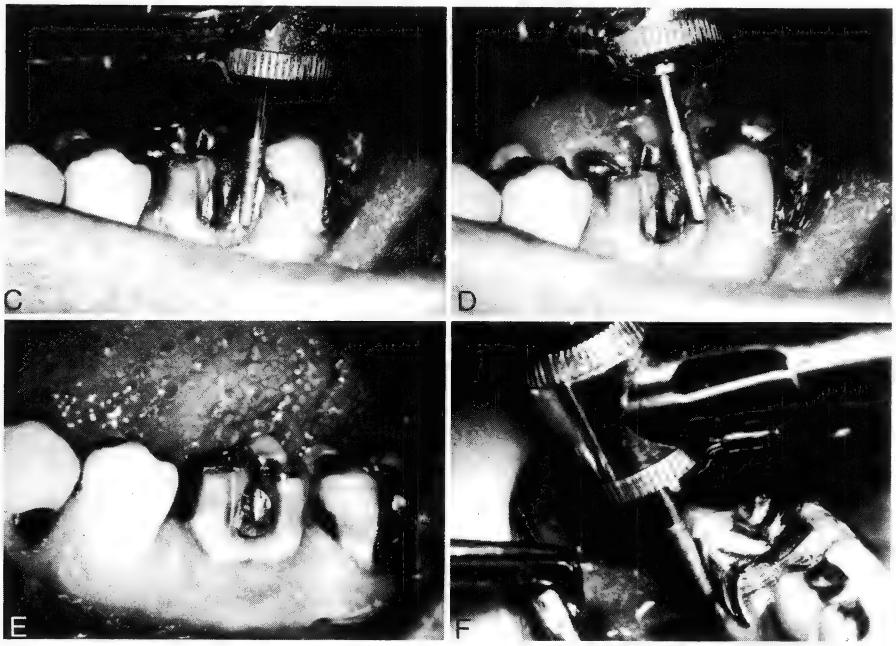


A

FACIAL & LINGUAL DEPTH CUTS

Instrument:	tapered round-end diamond
Form:	two planes terminates as a chamfer
Depth:	0.7 to 1.0 mm 0.3 to 0.5 mm cervically
Extension:	length adequate for retention ideally terminates on enamel ideally terminates supragingivally

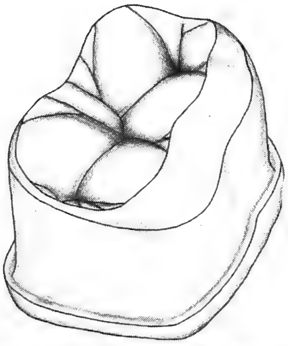
B



C D E F

FIGURE 4–5

A, Facial and lingual depth cuts.
B, Procedures for facial and lingual depth cuts.
C, Mesiofacial depth cut formed and instrument aligned with cervical aspect of facial contour as next depth cut is developed.
D, Instrument angulation changed so depth cut follows occlusal aspect of facial contour.
E, Facial depth cuts formed.
F, Lingual depth cuts being formed.



A

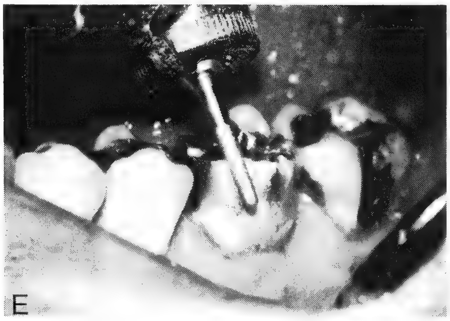
FACIAL & LINGUAL REDUCTION

Instrument:	tapered round-end diamond
Form:	two planes terminates as a chamfer
Depth:	0.7 to 1.0 mm 0.3 to 0.5 mm cervically
Extension:	join proximal reductions length adequate for retention ideally terminates on enamel ideally terminates supragingivally

B

C

D



E

FIGURE 4–6

A, Facial and lingual reduction.
B, Procedures for facial and lingual reduction.
C, Tooth structure being removed between depth cuts.
D, Cervical aspect of facial reduction extended to join reduced proximal surfaces.
E, Reduction of occlusal aspect of facial surface.

ideally terminates supragingivally and on enamel. However, the need to cover existing restorations by extending onto sound tooth structure and the length requirements for retention must take precedence. The occlusal part of each depth cut is accomplished next.

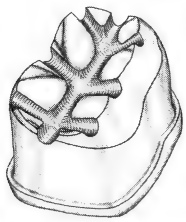
The tooth structure located between the depth cuts is removed using the same instrument and the reduction extended to join the reduced proximal surfaces (Fig. 4–6). The angulations established by the depth cuts are maintained in the overall reduction of the facial and lingual surfaces.

Occlusal Reduction

The occlusal surface must be uniformly reduced by a minimum of 1 to 1.5 mm to allow adequate thickness of restorative material so that the required strength and anatomic form can be developed in the restoration.

Occlusal depth cuts are placed (Fig. 4–7) using the tapered round-end diamond instrument, with the instrument being held parallel to existing occlusal grooves whenever possible and following the anatomic contour of the occlusal surface. The tooth structure remaining between the depth cuts is then uniformly removed to complete the occlusal reduction (Fig. 4–8A, B, C). The mandible is closed so the clearance between the prepared and opposing teeth can be evaluated for adequacy. A space of 1 to 1.5 mm must be present in both centric occlusion and throughout eccentric mandibular movements. Having the patient bite into a strip of wax*

*Trubyte equalizing wax, Dentsply International, York, PA.



A

OCCLUSAL DEPTH CUTS

Instrument: tapered round-end diamond
Form: follows anatomical contour
Depth: 1.0 to 1.5 mm
Extension: from reduced axial surfaces to center of tooth

B

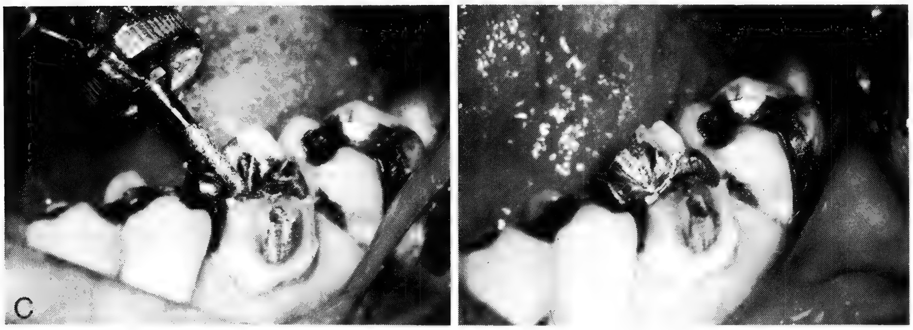


FIGURE 4–7

A, Occlusal depth cuts.
B, Procedures for occlusal depth cuts.
C, Diamond instrument used to form depth cuts.
D, Depth cuts formed.

allows the clearance to be measured in nonvisible areas of the occlusal surface (Fig. 4–8D, E).

Smoothing the Preparation and Rounding Line Angles

All prepared surfaces should be refined by using the same size diamond instrument with a finer grit to smooth the surfaces. The finish line should be refined so it has uniform depth and is devoid of rough areas and extreme undulations. Better fitting restorations can be made for smooth preparations with well-defined smooth finish lines.

The sharp line angles present where the various surface reductions meet should be rounded (Fig. 4–9). This procedure reduces the stress that develops when occlusal forces are applied to the restoration. Also, when dental stone is poured into the impression of the prepared tooth, round line angles reduce the possibility of trapping of air bubbles, which results in voids in the die. Likewise, when the wax pattern is invested there is less likelihood that air will be trapped and cause internal nodules on the casting.

The final smoothing of the prepared tooth surfaces should be done in the absence of water spray to maximize visual perception. The use of air as a coolant and short-term intermittent contact of the abrasive instrument with the tooth allow the refinement of the preparation to be accomplished without pulpal damage.

Alternative Order of Procedure

Some individuals prefer to reduce the occlusal surface first (Fig. 4–10). This sequence allows better visual access, particularly distally, when long teeth are encountered or when the finish line must be placed deep into the gingival crevice. Another advantage is that shorter rotary instruments can be used for the axial reduction.

Evaluation of Preparation Form

The most important aspects of tooth reduction relate to understanding and visualizing those characteristics that make up a good preparation and the realization that modifications must be implemented when a good tooth preparation has not or cannot be achieved. The long-term success of a fixed prosthesis depends on many factors but must begin with good tooth preparation.

AUXILIARY RETENTION AND RESISTANCE FORM

The form, condition, or amount of tooth structure located occlusal to the periodontium may not allow for the development of sufficient retention and resistance form in the completed preparation, although the preparation was properly executed. Also, removal of a prosthesis that has failed prematurely may reveal inadequately prepared teeth. These situations necessitate preparation modifications such as boxes, grooves, or pinholes to provide increased retention and resistance form. These features are aligned as parallel as possible to the path of insertion in order to resist occlusal forces that would otherwise dislodge the prosthesis.

Boxes improve the overall retention and resistance form more than do grooves or pinholes. Likewise,

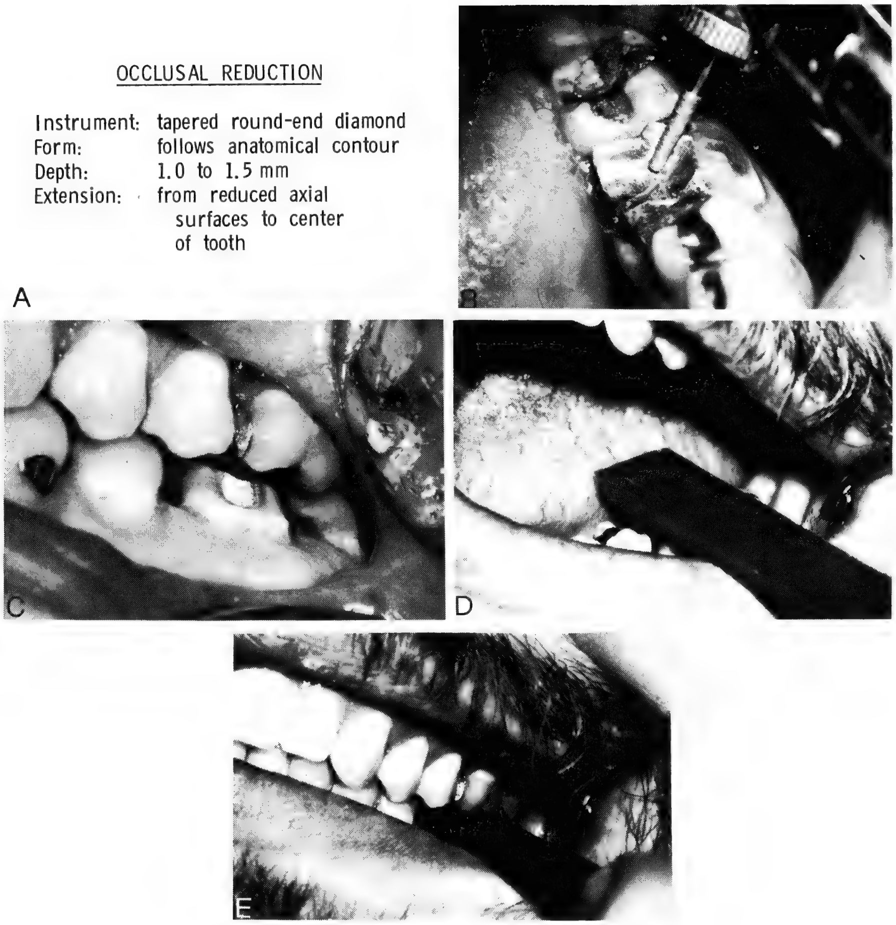


FIGURE 4–8

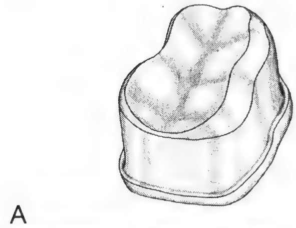
A, Procedures for occlusal reduction.
B, Occlusal surface being uniformly reduced following the depth cuts.
C, Occlusal clearance being checked.
D, Strip of wax positioned over prepared tooth.
E, Teeth brought into contact so wax is indented by opposing teeth and occlusal clearance can be measured.

grooves are more effective than pinholes. However, the dimension of boxes prevents their use with certain teeth, and grooves or pinholes should then be used. The type of preparation modification used depends on the amount of additional retention and resistance that is needed and the available tooth structure into which the modification can be placed. Boxes and grooves are placed around the prepared perimeter, and they require axial wall height, which may not be available on certain anterior teeth, whereas pinholes can be effectively placed in short teeth.

Boxes and grooves are the most common means of modifying posterior tooth preparations to improve retention and resistance form. For full-coverage retainers, they are best placed on proximal surfaces. This location optimizes resistance to faciolingual forces that attempt to dislodge the prosthesis. Mesiodistal dislodging forces are often adequately resisted by the distance between the prepared teeth and the usual parallelism, as discussed in Chapter 3. In cases in which proximal boxes or grooves alone do not provide sufficient additional resistance to dislodgment, facial and lingual boxes or grooves can be added.

Proximal boxes used to supplement retention and to increase stability should be placed in the center of the proximal surface and extend cervically to the beginning of the proximal chamfer. They must conform to the principles of the ideal 3- to 5-degree taper even if the proximal surfaces do not. They also must be compatible with the path of insertion. Depths of 0.5 to 1.0 mm pulpally and widths of 2.0 to 2.5 mm are usually adequate. The actual size of an auxiliary proximal box may be dictated by caries or a restoration and may not be completely controllable by the dentist.

Facial and lingual surfaces requiring additional retentive features are most frequently modified with the use of grooves rather than boxes, although boxes may be indicated when the existence of caries or restorative material makes impossible the placement of grooves in sound tooth structure. Grooves should be parallel to the path of insertion and approximately 0.5 mm deep.



B

SMOOTHING PREPARATION
ROUNDING LINE ANGLES

Instruments: fine grit tapered round-end diamond
1170 carbide bur
carborundum stone

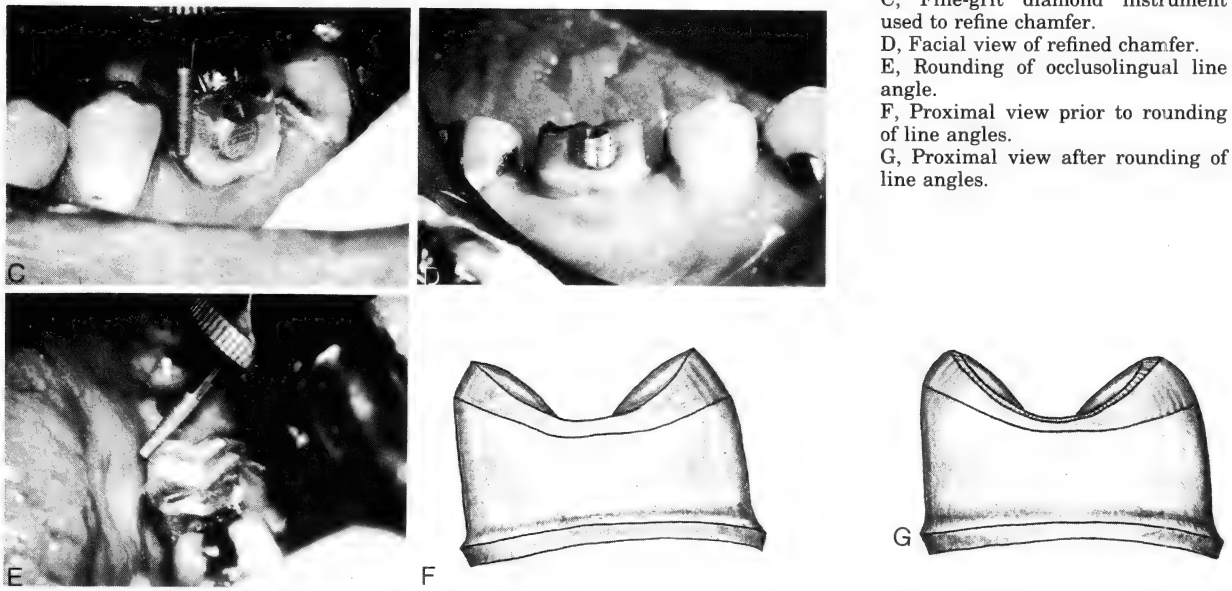


FIGURE 4–9

A, Completed preparation.
B, Procedures for smoothing preparation and rounding line angles.
C, Fine-grit diamond instrument used to refine chamfer.
D, Facial view of refined chamfer.
E, Rounding of occlusolingual line angle.
F, Proximal view prior to rounding of line angles.
G, Proximal view after rounding of line angles.

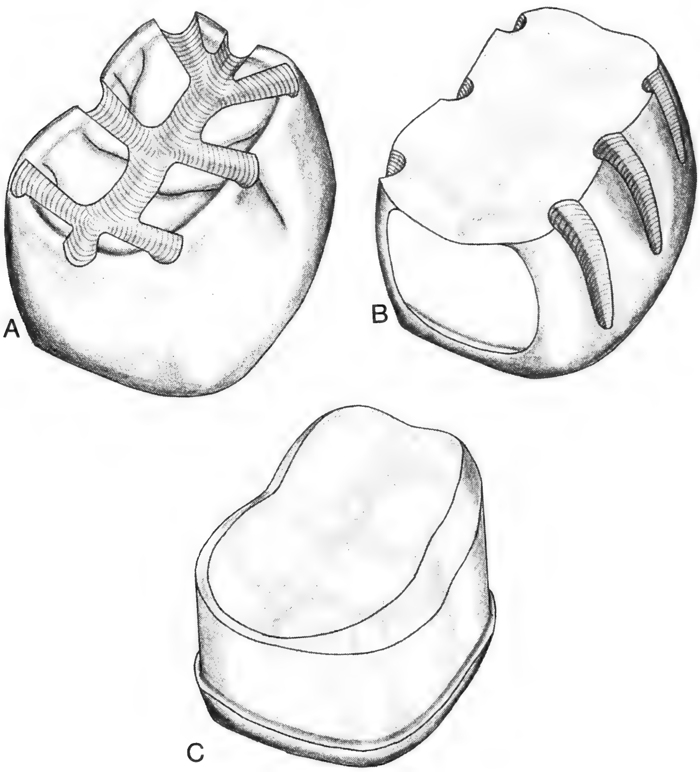


FIGURE 4–10 Alternative Order of Reduction

A, Occlusal depth cuts placed first.
B, Occlusal reduction completed and followed by proximal reduction and facial depth cuts.
C, Completed preparation.

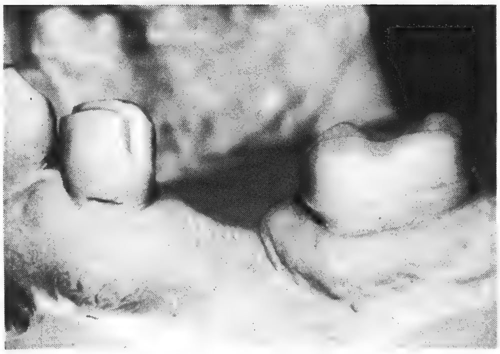


FIGURE 4–11 Slightly tipped mandibular molar. Malalignment was corrected by increasing the amount of proximal reduction.

Teeth that cannot be modified with auxiliary features to adequately increase retention and resistance form should be built up, if possible, with a restorative material that is well retained into sound tooth structure and that is not part of the final prosthesis. Such procedures, which allow the retainer to grasp both tooth structure and firmly anchored restorative material, are discussed in Chapter 27. When an abutment tooth cannot be built up or modified to provide sufficient retention and resistance form, a fixed prosthesis is contraindicated.

PREPARING MALALIGNED TEETH

When only a small amount of tipping or rotation has occurred, the usual preparation procedures and form can be accomplished by increasing the tooth reduction in certain areas and, when possible, by reducing the amount of reduction on the opposing surface (Fig. 4–11).

With moderate mesial or lingual tipping it may be necessary to modify the usual preparation form to avoid pulpal damage (Fig. 4–12). If a molar is mesially inclined, a knife edge finish line on the mesial surface provides adequate thickness of material for strength in the final prosthesis and keeps the axial reduction further from the pulp than if a chamfer or shoulder were used. Limiting the cervical extension of the finish line on surfaces toward which the tooth is tipped also helps to prevent pulpal encroachment. Adequate overall resistance to dislodgment can often be achieved by increasing the length of other axial walls and placing auxiliary retentive features in areas of the preparation not likely to be in close proximity to the pulp.

Endodontic treatment of some malaligned abutment teeth may allow correction of a discrepancy in the path of insertion, whereas alignment of other severely tipped or rotated abutment teeth may not be possible even with devitalization. In these situations and whenever significant malalignment is present, orthodontic treatment may be indicated to correct the alignment discrepancy prior to tooth preparation.

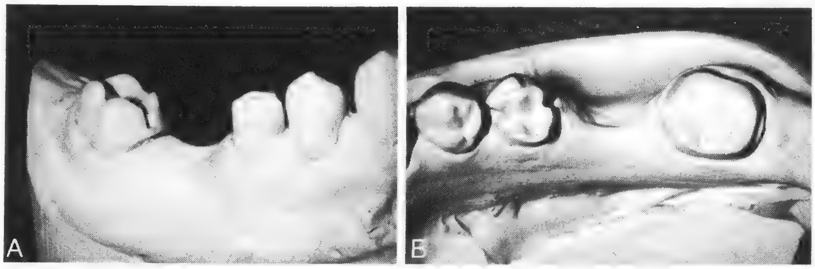


FIGURE 4–12

A, Moderately tipped mandibular molar. Mesial reduction terminates in a knife edge, and a mesial groove was used.
B, Occlusal view. Note that chamfer depth on the molar was increased distally to achieve the proper degree of taper between mesial and distal walls.

5

The Posterior Partial Veneer Crown

A partial veneer crown is an extracoronal cast restoration that usually covers the occlusal and all but one of the axial surfaces of a tooth. The facial surface is most often the area not involved. This restoration may be used as a single-unit restoration or as a retainer for a fixed prosthesis. In general, because of its more conservative design, the partial veneer restoration should be used instead of the full veneer restoration whenever possible.

ADVANTAGES

Partial veneer restorations have several advantages over full-coverage crowns. (1) They are more conservative because less tooth structure must be removed. (2) The periodontal response to the restoration is potentially more favorable, since the surface left untouched should allow the soft tissue to react similarly to that of any unrestored tooth in the same environment. Since the facial periodontal tissues seem to respond less favorably to undesirable stimuli than do the tissues adjacent to other areas of the tooth, omitting the facial surface from the preparation for a restoration is often highly desirable. (3) Esthetically, a partial veneer crown is far superior to a full veneer cast crown. Also, when unique tooth colors are present or there is considerable gingival recession, a partial veneer crown may provide a more pleasing overall esthetic result than can be developed in a metal-ceramic crown.

The posterior partial veneer crown often is distinctively advantageous as a single restoration over the MOD inlay or the MOD onlay. The MOD inlay restoration acts as a wedge and can induce tooth fracture. While the onlay compensates for this by covering the buccal and lingual cusps, the preparation also shortens the overall length of the tooth, requiring cervical extension of the boxes, which is often much greater than that required to achieve adequate retention for a partial veneer crown.

DISADVANTAGES

Partial veneer crowns have three main disadvantages. (1) There is usually some display of metal, although skillful execution of the preparation and proper education of the patient concerning its biologic advantages aid in compensating for this disadvantage. Also, the design can sometimes be modified to eliminate visible metal. (2) Since a major surface of the tooth is not included, this restoration may not have retentive qualities equal to the full veneer crown's. (3) The partial veneer restoration may not always have the required rigidity, especially when it is being used as a retainer for a fixed prosthesis. The reduced rigidity is caused by the design, which does not completely encircle the tooth.

INDICATIONS

The partial veneer crown is indicated on posterior teeth that have the following characteristics:

1. The coronal tooth structure is intact or minimally restored.
2. Normal crown form exists, that is, not a conical form.
3. There is average or greater crown length.

If the restoration is to be used as a retainer, the following considerations also apply:

1. The abutment teeth are in reasonable axial alignment.
2. The edentulous span is relatively short (one or two teeth are missing).
3. There are average or below average occlusal forces.

THE MAXILLARY POSTERIOR PARTIAL VENEER CROWN PREPARATION

The preparation design for both maxillary molars and premolars is identical. However, owing to poor accessi-

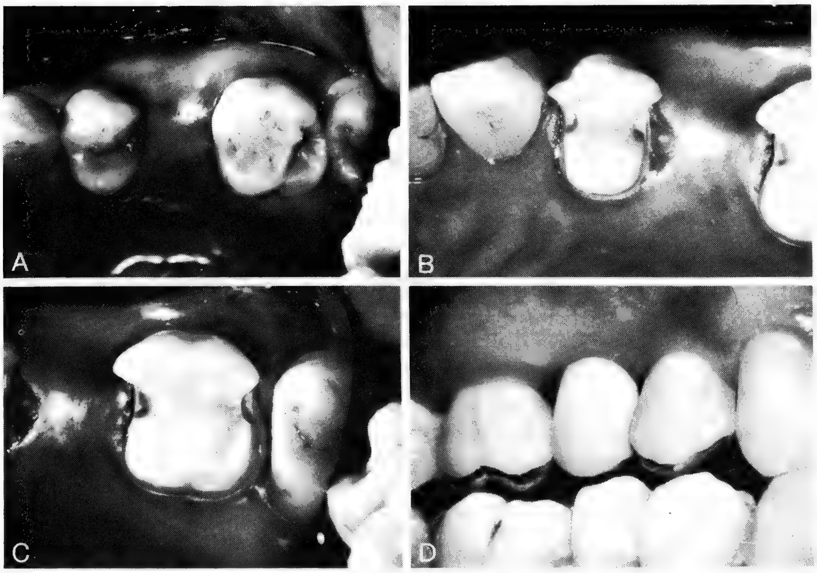


FIGURE 5–1
A, Maxillary premolar and molar.
B, Maxillary premolar partial veneer crown preparation.
C, Maxillary molar partial veneer crown preparation.
D, Facial view of three-unit fixed partial denture utilizing partial veneer crowns and metal-ceramic pontic.

bility and a shorter occlusocervical crown dimension, partial veneer crowns are seldom used on maxillary second molars. The facial surface remains largely untouched with proximal boxes providing the required retention and resistance form. The only involvement of the facial surface is an occlusal bevel, which allows the restoration to encompass the cusp tip and cusp arms, thereby preventing fracture of facial tooth structure when occlusal forces are applied to the restoration (Fig. 5–1).

Proximal Reduction

The first step is the reduction of the proximal surfaces (Fig. 5–2). This is done by using a tapered round-end coarse-* or medium-grit† diamond, held parallel to the path of insertion to produce a taper of 3 to 5 degrees that terminates in a chamfer having a pulpal depth of 0.3 to 0.5 mm. When little proximal space is present, an instrument‡ with a smaller diameter can be used. If done skillfully, the chamfer thus formed needs only minimal alteration to establish the final cervical finishing line interproximally. Ideally this cut should terminate supragingivally on enamel. The proximal reduction is carried facially into the area of proximal contact with care being taken to avoid damage to the adjacent tooth. Also, care must be taken to avoid facial overextension, which would cause an unnecessary display of metal. When the proximal reduction is properly executed, there is a lip of enamel remaining lingually to the facioproximal line angle, which can be blended into the proximal box during a later step.

*Two Striper 767.7C, Premier Dental Products Co., Philadelphia, PA 19107.
†Blu-White 1DT, Teledyne Densco, Denver, CO 80207.
‡Blu-White 1/2 DT, Teledyne Densco, Denver, CO 80207.

Lingual Reduction

As described for the full veneer crown preparation, depth cuts greatly aid in accurate and uniform reduction of certain axial surfaces (Fig. 5–3). These cuts are made with the same instrument that is used for the proximal reduction, the tapered round-end medium-grit diamond. The cuts are made in two planes to follow the occlusocervical contour of the lingual surface. For premolars, one depth cut centered on the lingual surface provides an adequate reduction guide. For molars, two such cuts aligned with the lingual cusp tips generally suffice. The depth cuts are 0.7 to 1.0 mm deep occlusally and terminate cervically as chamfers, 0.3 to 0.5 mm deep. They should be extended sufficiently far cervically that adequate length for retention is established. Again, the ideal termination of the cut is supragingival and on enamel.

Using the same diamond instrument, the remaining lingual tooth structure is reduced to the level of the depth cuts, with care taken to retain the two-plane contour established by the depth cuts (Fig. 5–4). The reduction extends just beyond the linguoproximal line angles, joining with the proximal reduction already accomplished.

Occlusal Reduction

Depth cuts are first placed to a depth of 1.0 to 1.5 mm following the occlusal groove pattern (Fig. 5–5). They taper out as the facial cusp is approached to avoid excessive reduction of this area, which would lead to an excessive display of gold over the buccal cusp. Otherwise they are of uniform depth, following the anatomic contour of the occlusal surface. They extend from the already reduced lingual surface to the buccal cusp. The central depth cut extends across the tooth mesiodistally, following the central groove. The cuts are made with the tapered round-end diamond already described.

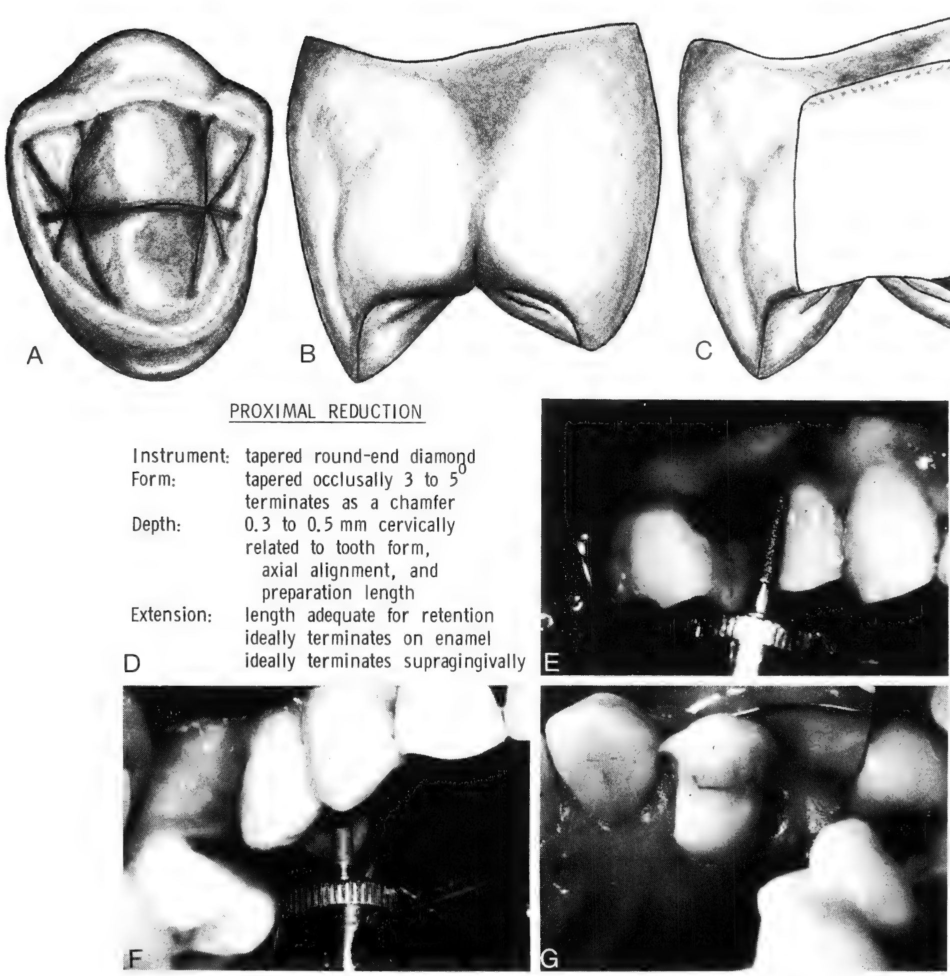


FIGURE 5–2

A, Occlusal view of maxillary premolar.
B, Proximal view of maxillary premolar.
C, Maxillary premolar after proximal reduction.
D, Procedures for proximal reduction.
E, Diamond instrument aligned with path of insertion.
F, Mesial surface being reduced.
G, Occlusal view of reduced proximal surfaces.

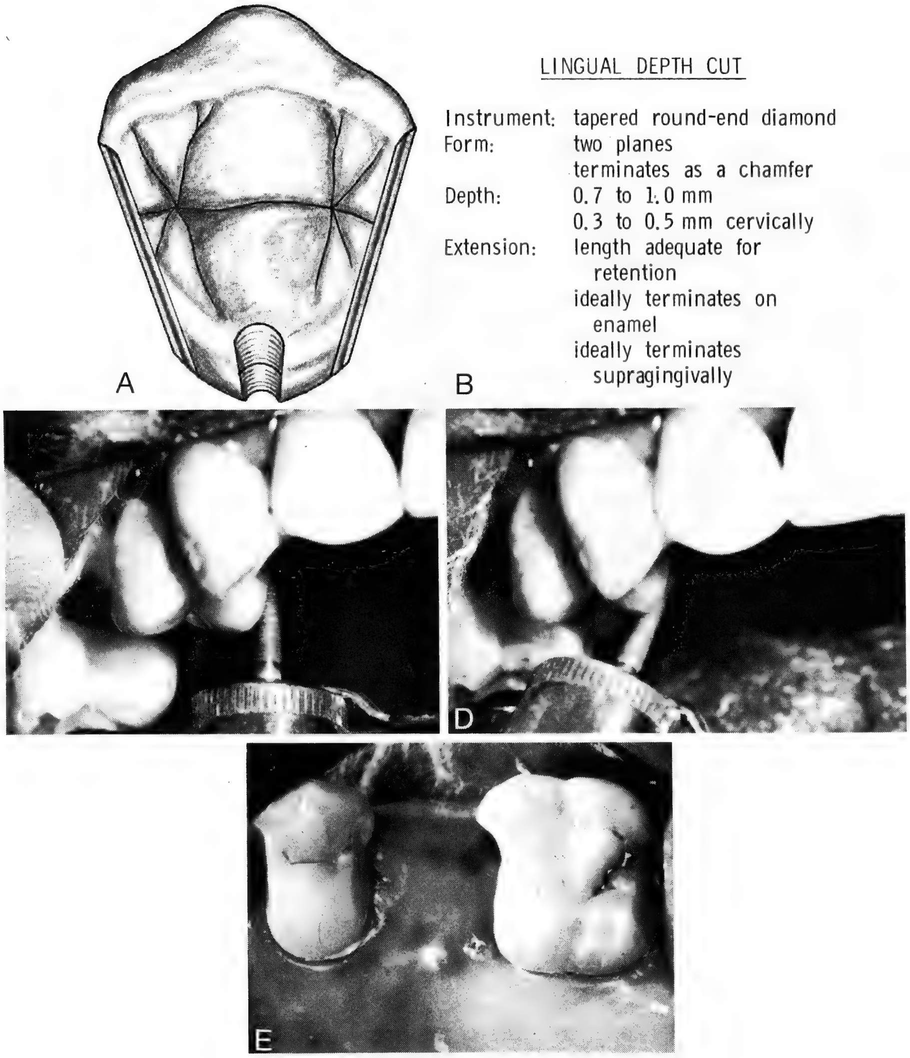


FIGURE 5–3

A, Lingual depth cut.
B, Procedures for lingual depth cut.
C, Cervical aspect of depth cut being formed.
D, Instrument alignment changed to coincide with occlusal portion of lingual surface.
E, Single depth cut formed in premolar and three cuts placed in molar.

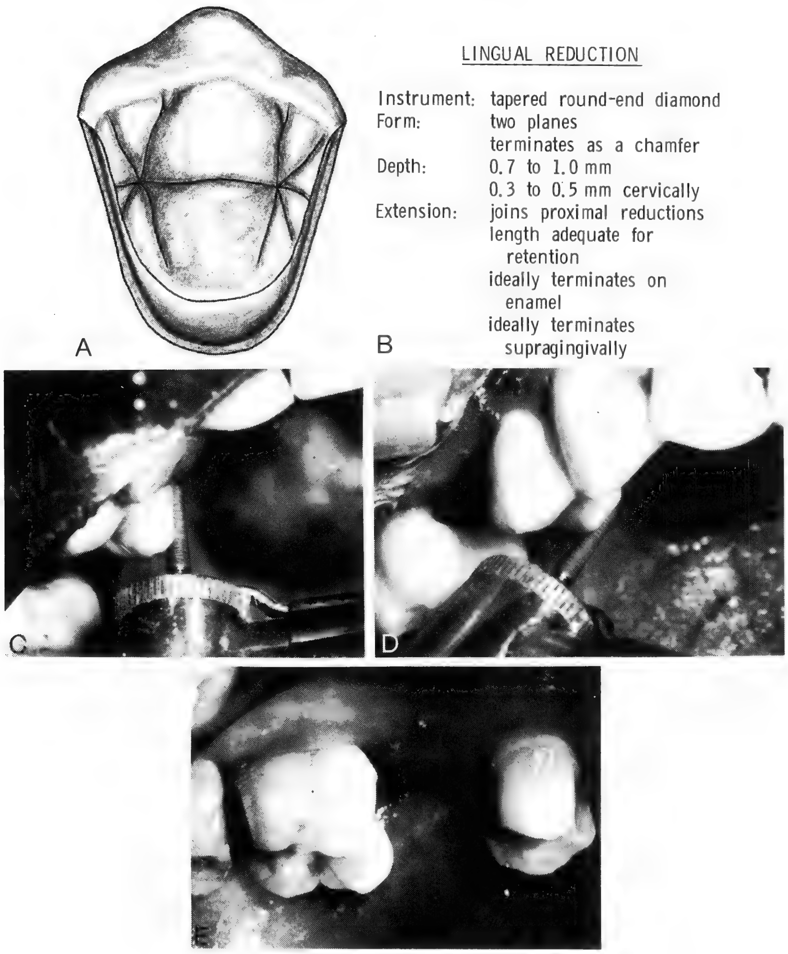


FIGURE 5–4
A, Reduced lingual surface.
B, Procedures for lingual reduction.
C, Reduction of cervical aspect of lingual surface.
D, Reduction of occlusal aspect of lingual surface.
E, Reduced lingual surfaces.

Using the same diamond instrument, the remaining occlusal surface is uniformly reduced following the anatomic contour (Fig. 5–6). Care should be taken to avoid overreduction of the buccal cusp or cusps.

Proximal Boxes

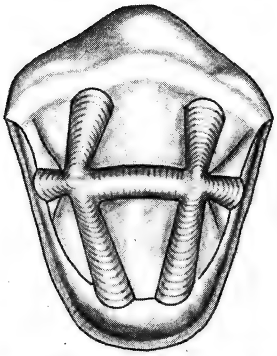
For the greatest effect on retention and resistance form, the proximal boxes are located in the facial one-half of the proximal surface (Fig. 5–7). They are formed with a 56L or 57L carbide bur. Mesiodistally, they are aligned with the previously established 3- to 5-degree taper of the proximal surfaces. The faciolingual angulation must be compatible with the lingual surface and, of course, with the path of insertion when the crown is being used as a retainer. The box depth is 0.5 mm cervically. This is in addition to the previous proximal reduction, so that the total reduction depth is 0.8 to 1.0 mm at the cervical extent. The faciolingual width should be from 1.3 to 1.7 mm. The box extends cervically to the beginning of the previously established chamfer finishing line.

Facial Flare of Proximal Box

Once the proximal box is established, its facial aspect is flared facially with a suitable binangle chisel or a hatchet (Fig. 5–8). This smoothes that surface of the box, blends the lip of enamel left by the original proximal reduction into the box form, and creates a facial margin that meets the unprepared surface of the tooth at approximately a 90-degree angle. It is important to establish nonacute angles at the surface termination of preparation cuts in order to avoid chipping of the margins as a result of the inherent friability of a sharp enamel margin. The flare is extended facially to a point just past the proximal contact area in order to reach a cleansable area, but for esthetic reasons the margin should terminate lingually to the facioproximal line angle.

Facial Cusp Bevel

The facial aspect of the buccal cusp or cusps is beveled at an angle that is approximately 45 degrees relative to the facial surface (Fig. 5–9A, B, D, E). This provides a satisfactory termination of the preparation and allows a thickness of metal sufficient to protect the facial cusp against fracture. The bevel is accomplished with a 56L or 169L carbide bur, has a width of 0.5 to 0.8 mm, and extends mesiodistally to join with the facial flare of the proximal boxes.



A

OCCLUSAL DEPTH CUTS

Instrument:	tapered round-end diamond
Form:	follows anatomical contour
Depth:	1.0 to 1.5 mm tapers out as facial cusp is approached
Extension:	from reduced lingual surface to facial cusp

B

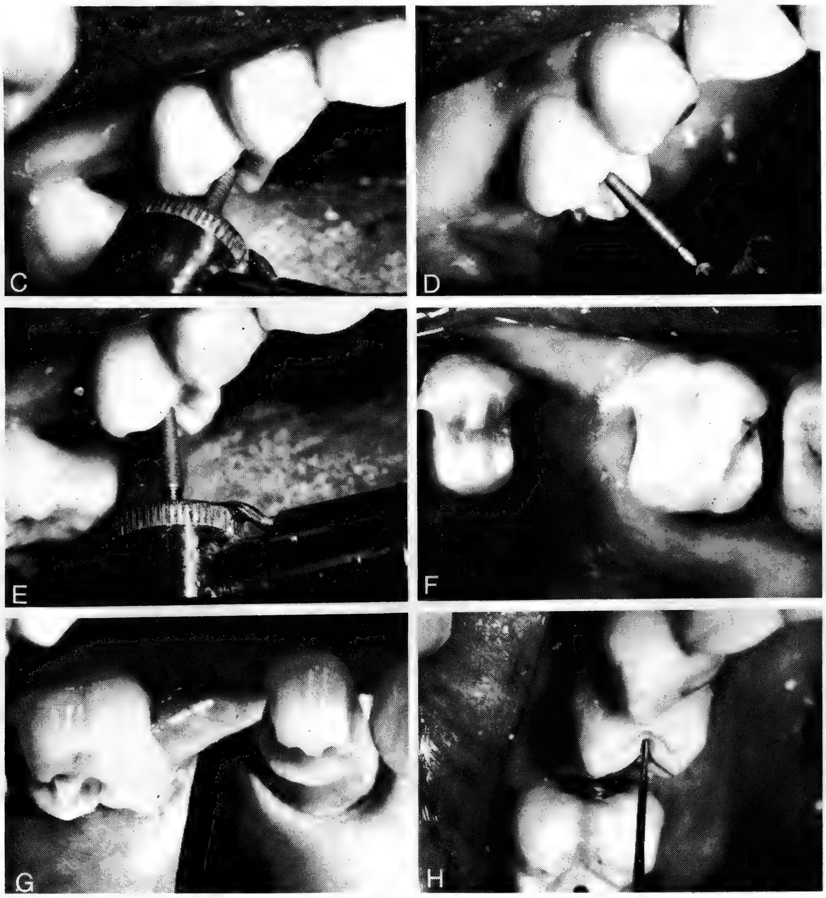


FIGURE 5–5

A, Occlusal depth cuts.
B, Procedures for occlusal depth cuts.
C, Occlusal depth cuts placed in facial one-half of tooth.
D, Occlusal depth cuts placed in lingual one-half of tooth.
E, Depth cut being formed along central groove.
F, Occlusal view of depth cuts.
G, Lingual view of depth cuts.
H, Occlusal depth cut measured with a periodontal probe.

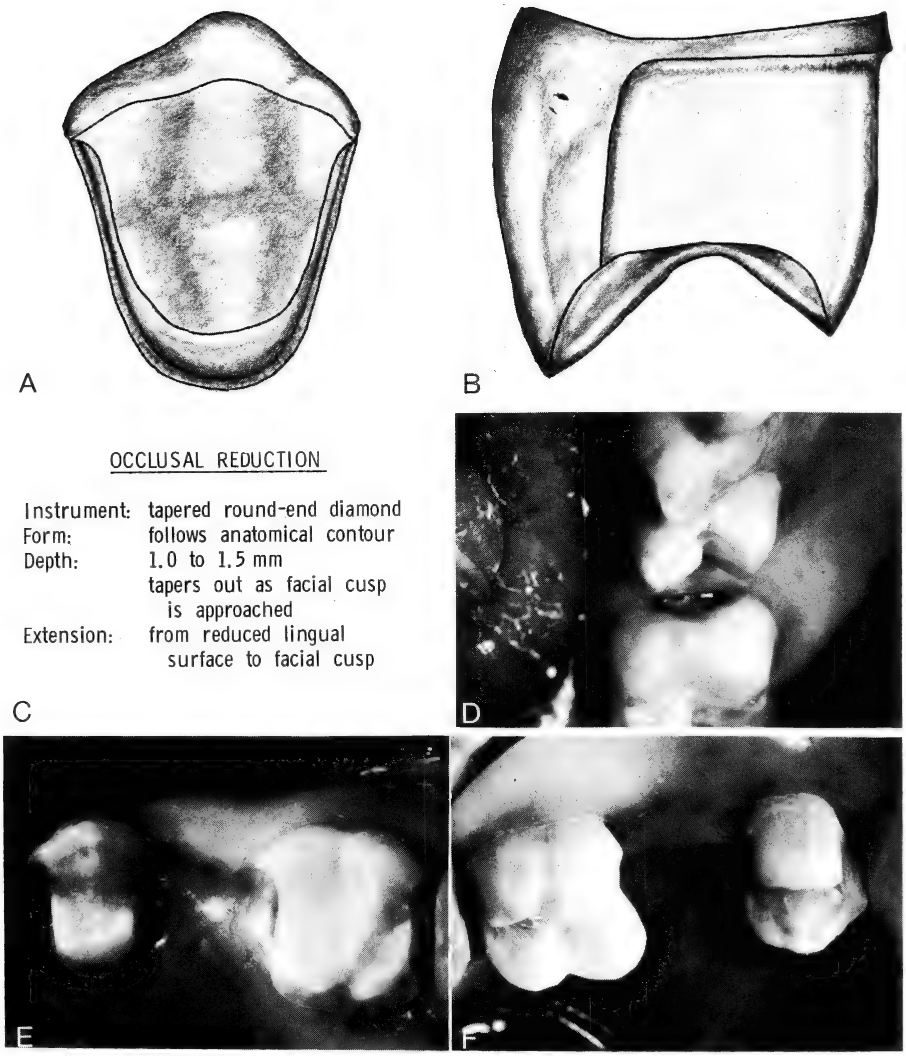
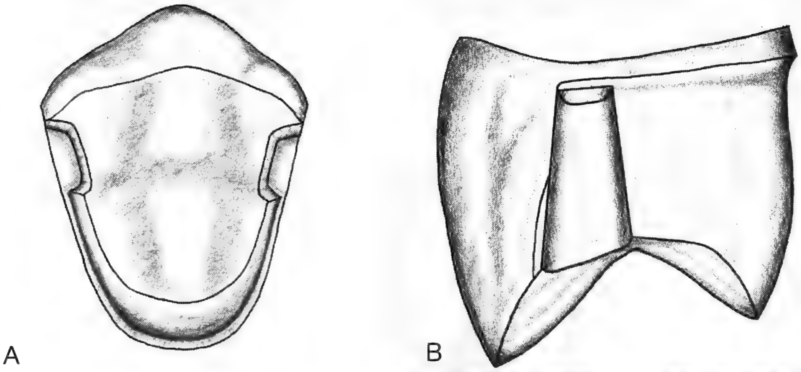


FIGURE 5–6

A, Occlusal view of reduced occlusal surface.
B, Proximal view of reduced occlusal surface.
C, Procedures for occlusal reduction.
D, Lingual one-half of occlusal surface reduced.
E, Occlusal reduction, occlusal view.
F, Occlusal reduction, lingual view.



A

B

FIGURE 5–7

A, Occlusal view of proximal boxes.
B, Proximal view of proximal boxes.
C, Procedures for forming proximal boxes.
D, 56L carbide bur used to form boxes.
E, Small box formed so its depth and location can be visually verified.
F, Box extended to final dimensions.

PROXIMAL BOXES

Instrument:	56L or 57L carbide bur
Form:	tapered occlusally 3 to 5^0
Location:	in facial ½ of crown
Angulation:	parallel to path of insertion
Depth:	0.5 mm after proximal reduction 0.8 to 1.0 mm total
Width:	1.3 to 1.7 mm
Extension:	to beginning of chamfer

C

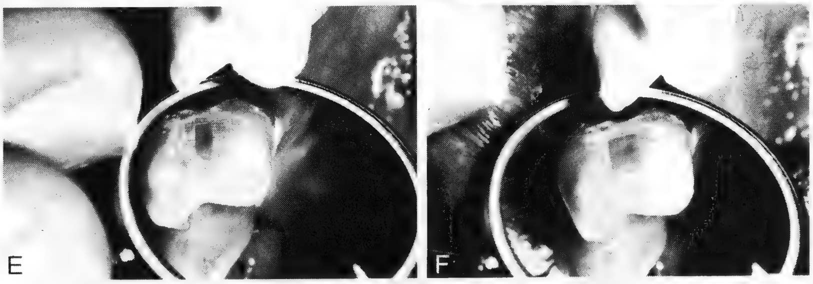
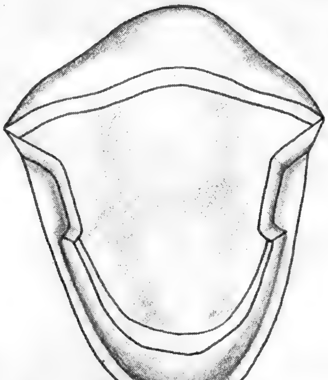


FIGURE 5–8

A, Facial walls of proximal boxes flared facially.
B, Procedures for forming facial flair.
C, Hatchet used to flare facial walls.
D, Flare extended just facial to proximal contact.

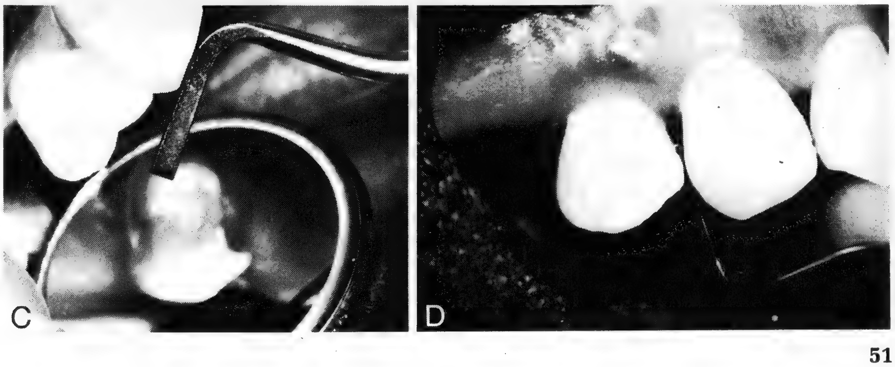


A

FACIAL FLARE OF PROXIMAL BOXES

Instruments:	bin angle chisel hatchet
Form:	meet unprepared tooth surface at 90^0
Extension:	include proximal contacts to cleansable area terminates lingual to facioproximal line angle if possible

B



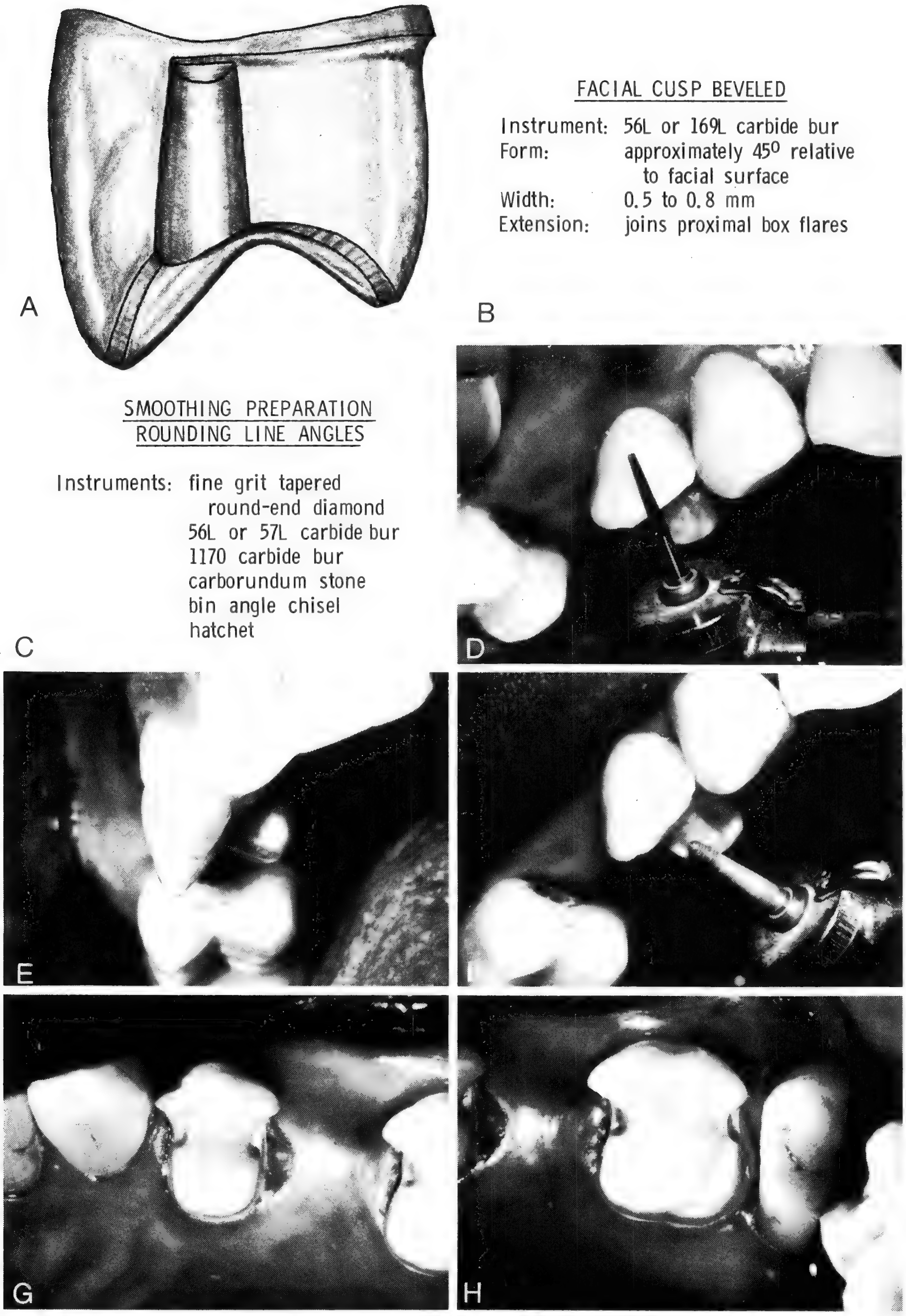


FIGURE 5–9

A, Facial cusp beveled, line angles rounded, and preparation smoothed.
B, Procedures for beveling facial cusp.
C, Procedures for smoothing preparation and rounding line angles.
D, 169L carbide bur used to bevel facial cusp.
E, Proximal view of beveled cusp.
F, Fine-grit diamond used to smooth preparation.
G, Occlusal view of completed premolar preparation.
H, Occlusal view of completed molar preparation.

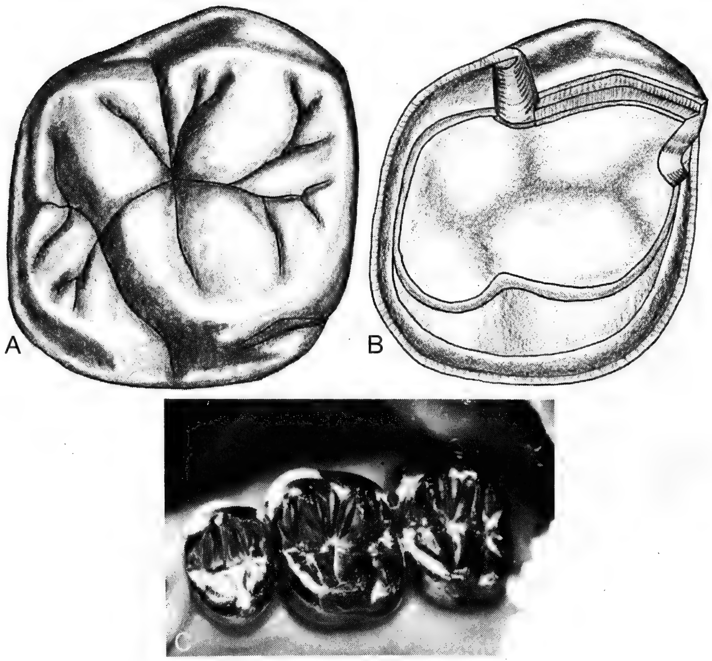


FIGURE 5–10
A, Maxillary first molar.
B, Seven-eighths partial veneer crown preparation.
C, Conventional partial veneer crown on maxillary premolar, seven-eighths crown on maxillary first molar, and full veneer crown on second molar.

Smoothing Preparation and Rounding of Line Angles

Once the basic preparation has been formed, all of the cut surfaces are smoothed and refined (Fig. 5–9A, C, F, G, H). The usual instrument used is a finishing grit diamond of the same size and shape as was used to make most of the basic cuts. However, a Carborundum stone or carbide bur of the appropriate size and shape may be substituted to achieve an even smoother result. The boxes may be refined and bevels smoothed using instruments such as the 56L, 57L, or 1170 carbide burs and a binangle chisel or a hatchet.

MAXILLARY PREPARATION MODIFICATIONS

The Seven-Eighths Partial Veneer Crown

This is a restoration or retainer that is generally used on maxillary molars and occasionally on maxillary premolars that have extensive distal involvement by caries or a previous restoration making a proximal box ineffective. In order to achieve adequate retentive characteristics, the preparation is extended onto the facial surface. The usual extension is to the center of the facial surface, where the preparation can be terminated without excessive display of metal (Fig. 5–10A, B). The seven-eighths crown is often esthetically and biologically preferable to a full veneer cast crown (Fig. 5–10C).

Esthetic Modifications

When occlusal relationships permit, it is sometimes possible to alter partial veneer crown design to avoid the display of metal along the mesial arm of the facial cusp (Fig. 5–11). This is usually advisable only when there are neither centric nor eccentric occlusal contacts on the area not to be involved in the preparation. There may be exceptions when occlusal forces are judged to be so slight that there is little risk of either dislodging the abutment from the retainer or fracturing tooth structure. This modified preparation is limited to the maxil-

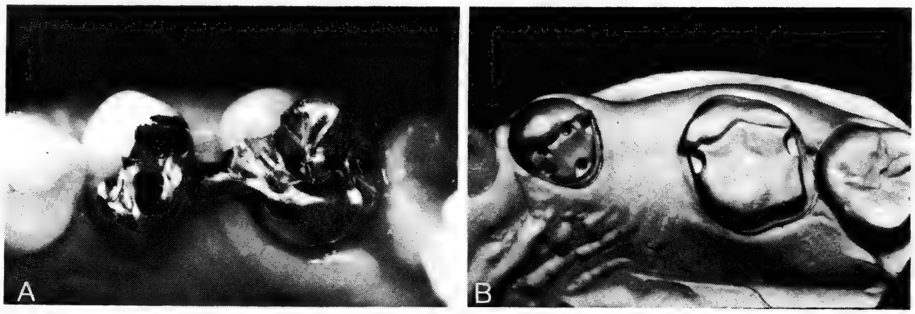


FIGURE 5–11
A, Three-unit prosthesis with modified preparations avoiding the mesial cusp arms on both the premolar and molar.
B, Maxillary molar partial veneer crown preparation not covering mesiobuccal cusp.

lary teeth and may be employed with both conventional partial veneers and seven-eighths crowns. Accessory grooves or pinholes may be added to the preparation to enhance retention and resistance form.

The termination of the occlusal reduction of the cusp not to be covered is abrupt, forming a vertical ledge that is parallel to the path of insertion. The amount of reduction should be no less than 1.0 mm and preferably more.

THE MANDIBULAR PREMOLAR PARTIAL VENEER CROWN PREPARATION

Morphologic differences between the mandibular premolar and the maxillary premolar require an altered preparation design if the partial veneer crown is to be successful (Fig. 5–12A, B). One difference to be taken into account is the much shorter length of the lingual cusp or cusps of the mandibular premolar. This is especially true of the mandibular first premolar. That characteristic causes the lingual surface and the lingual half of the proximal surfaces to be shorter than on other teeth, thus reducing the potential for adequate retention. In addition, the shortness of the lingual half of the proximal surfaces often makes the use of boxes impractical, since their lingual aspects would be quite short. Instead, it is usually advantageous to place grooves in the facial half of the proximal surface as the main retentive features (Fig. 5–12C, D). In addition, an accessory groove is placed in the distal aspect of the facial surface. This groove increases both the retention and the resistance form of the preparation and thus compensates for the reduced length of the lingual and proximal surfaces.

Initial Preparation Steps

The first three steps, proximal reduction (Fig. 5–13), lingual reduction (Fig. 5–14), and occlusal reduction (Fig. 5–15), are the same as for the maxillary premolar.

Proximal Grooves

The proximal grooves are made with a 170L carbide bur. They are located in the facial one-half of the proximal surfaces and aligned to be parallel to the path of insertion with a 3- to 5-degree convergence. They are 0.3 to 0.5 mm deep pulpally at the cervical termination, with a faciolingual width of 1 mm. The grooves terminate cervically at the beginning of the chamfer (Fig. 5–16).

Distobuccal Modification Groove

The distobuccal groove is placed with a 170L carbide bur or with a small-diameter round-end diamond instrument. It is centered in the distal one-half of the facial surface, aligned parallel to the path of insertion mesiodistally, but follows the facial contour occlusocervically. It is made 0.3 to 0.5 mm deep, with a width of approximately 1.0 mm, and it should taper occlusally 3 to 5 degrees. The groove terminates at, or slightly occlusally to, the level of the proximal chamfer (Fig. 5–17).

Distofacial Chamfer

A chamfer finishing line is formed to join the cervical extent of the distobuccal modification groove with the distal proximal chamfer (Fig. 5–18). It is made with the tapered round-end diamond instrument, and its depth is the same as the existing chamfer. Its configuration is that of an S curve if the modification groove is relatively

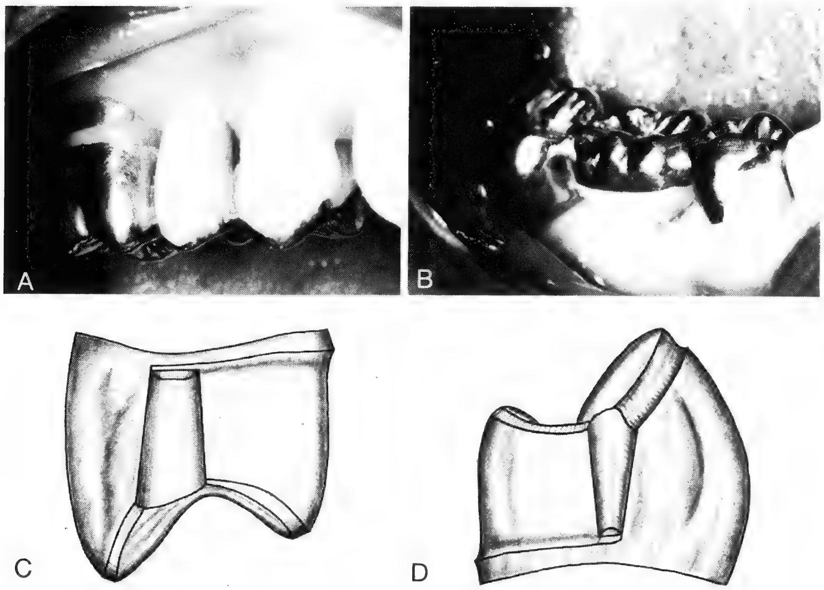
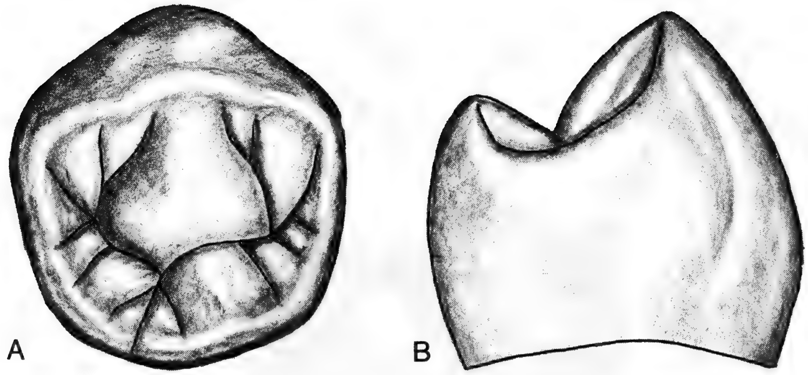
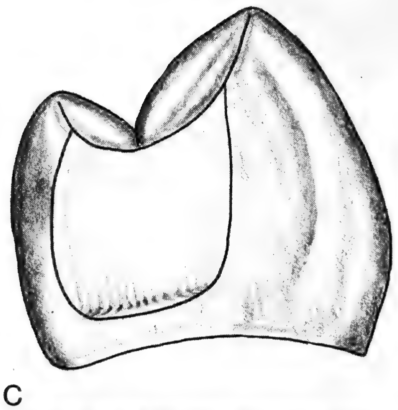


FIGURE 5–12

A, Three-unit maxillary prosthesis with partial veneer crown on maxillary premolar.
B, Three-unit mandibular prosthesis with alteration in design because of morphology of premolar. Note that casting extends onto the distal aspect of the facial surface.
C, Maxillary premolar partial veneer crown preparation showing proximal box.
D, Mandibular premolar partial veneer crown preparation showing proximal groove.





PROXIMAL REDUCTION

Instrument:	tapered round-end diamond
Form:	tapered occlusally 3 to 5° terminates as a chamfer
Depth:	0.3 to 0.5 mm cervically related to tooth form, axial alignment, and preparation length
Extension:	length adequate for retention ideally terminates on enamel ideally terminates supragingivally

D

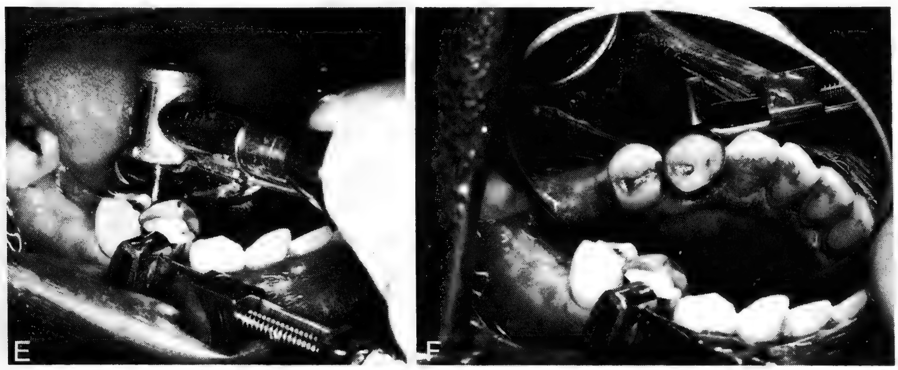
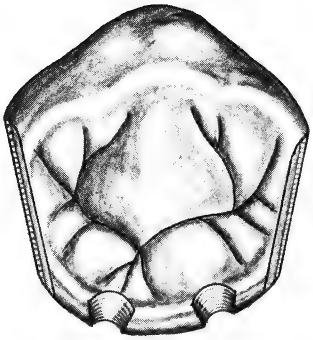
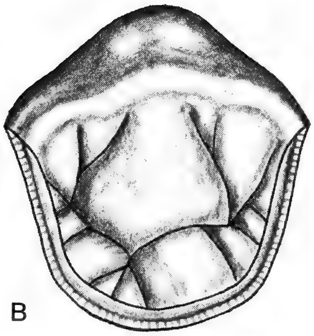


FIGURE 5–13

A, Occlusal view of mandibular second premolar prior to preparation.
B, Proximal view of mandibular premolar prior to preparation.
C, Proximal reduction.
D, Procedures for proximal reduction.
E, Reduction of mesial proximal surface. Note the presence of a matrix band to prevent abrasion of adjacent tooth.
F, Occlusal view of proximal reduction.



A



B

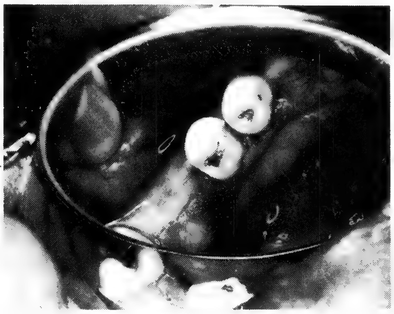
FIGURE 5–14

A, Lingual depth cuts.
B, Lingual surface reduced.
C, Procedures for lingual reduction.
D, Lingual depth cut placed and mesial one-half of lingual surface reduced.

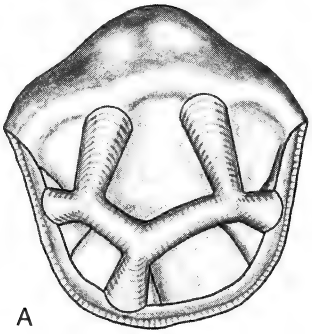
LINGUAL REDUCTION

Instrument:	tapered round-end diamond
Form:	two planes terminates as a chamfer
Depth:	0.7 to 1.0 mm 0.3 to 0.5 mm cervically
Extension:	joins proximal reduction length adequate for retention ideally terminates on enamel ideally terminates supragingivally

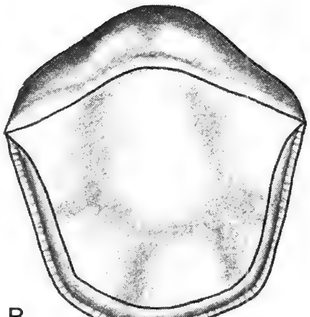
C



D



A



B

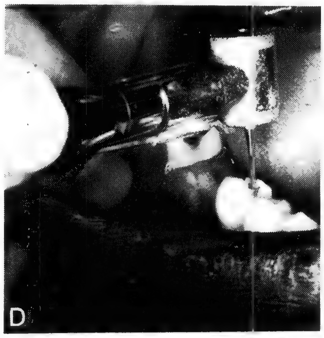
FIGURE 5–15

A, Occlusal depth cuts.
B, Occlusal surface reduced.
C, Procedures for occlusal reduction.
D, Occlusal depth cuts being placed.
E, Reduction of lingual portion of occlusal surface.
F, Reduction of facial portion of occlusal surface.

OCCLUSAL REDUCTION

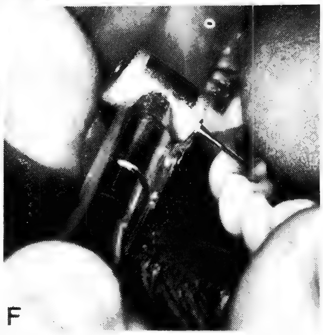
Instrument:	tapered round-end diamond
Form:	follows anatomical contour
Depth:	1.0 to 1.5 mm slightly less over facial cusp
Extension:	from reduced lingual surface to facial cusp

C

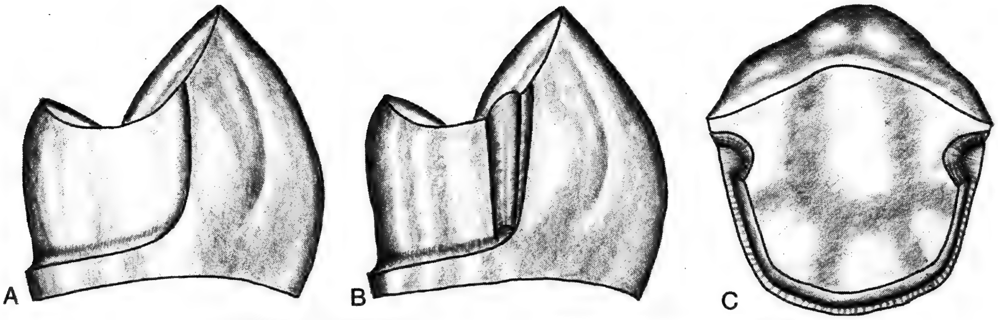


D

E



F



PROXIMAL GROOVES

Instrument:	170L carbide bur
Form:	tapered occlusally 3 to 5°
Location:	in facial ½ of crown
Angulation:	parallel to path of insertion
Depth:	0.3 to 0.5 mm cervically after proximal reduction
Width:	1.0 mm minimum
Extension:	to beginning of chamfer

D

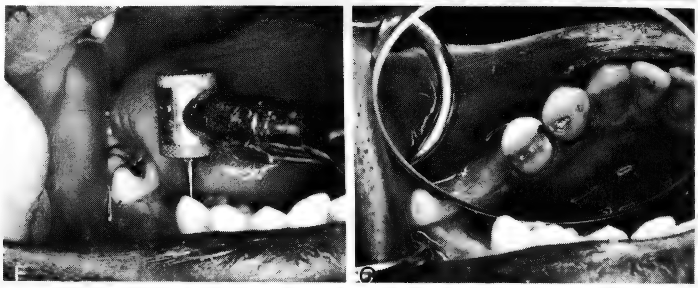


FIGURE 5–16

A, Mesial view prior to placement of proximal groove.
B, Mesial proximal groove formed.
C, Occlusal view of proximal grooves.
D, Procedures for forming proximal groove.
E, Placement of mesial proximal groove.
F, Placement of distal proximal groove.
G, Occlusal view of grooves.

short or it simply may be a straight line mesiodistally if the modification groove has the same length as the distal retentive groove. As this chamfer is formed, the ridge of tooth structure that remains between the two distal grooves is rounded to provide a smooth transition between the two.

Mesial Flare of the Modification Groove

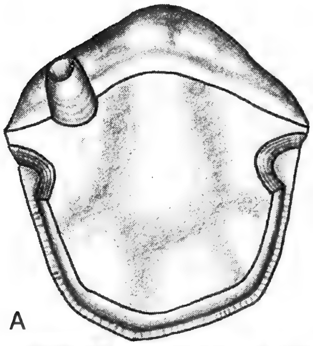
The mesial margin of the distal modification groove is flared slightly with a hatchet or binangle chisel in order to achieve a smooth finishing line and to eliminate any unsupported tooth structure, which might fracture on trial seating or finishing of the restoration (Fig. 5–19A, D).

Facial Flare of Mesial Groove

With a hatchet or binangle chisel, the mesial groove is flared facially to a cleansable area that is facial to the proximal contact area but lingual to the mesiofacial line angle (Fig. 5–19B, D, E).

Facial Cusp Bevel

In normal occlusion, the facial cusp of a mandibular premolar contacts the opposing tooth or teeth. The relationship requires that the cusp be included in the preparation and protected by at least 1.0 mm of metal in the final preparation. The best means of accomplishing this is by using a concave bevel that extends onto the facial surface a distance sufficient to reach past the

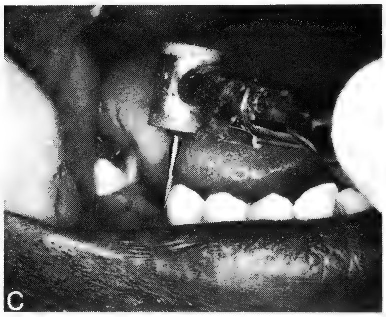


A

DISTOBUCCAL MODIFICATION GROOVE

Instrument:	170L carbide bur
Form:	tapered occlusally 3 to 5^0
Location:	centered in distal ½ of facial surface
Angulation:	parallel to path of insertion mesiodistally follow tooth contour faciolingually
Depth:	0.3 to 0.5 mm
Width:	1.0 mm
Extension:	terminates at or slightly above proximal chamfer

B



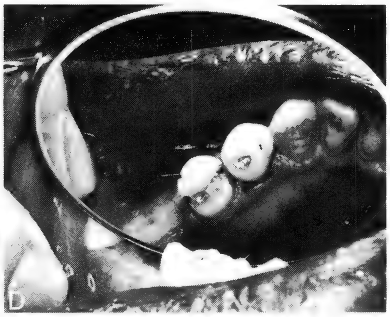


FIGURE 5–17

A, Distobuccal modification groove.
B, Procedures for forming distobuccal modification groove.
C, 170L carbide bur used to form groove.
D, Occlusal view of modification groove.

FIGURE 5–18

A, Procedures for forming distobuccal chamfer.
B, Chamfer formed between distobuccal modification groove and distal proximal groove.

DISTOBUCCAL CHAMFER

Instrument:	tapered round-end diamond
Depth:	0.3 to 0.5 mm
Extension:	joins distal chamfer

A

MESIAL FLARE OF DISTOBUCCAL MODIFICATION GROOVE

Instruments:	bin angle chisel hatchet
Extension:	eliminate unsupported tooth structure

A

FACIAL FLARE OF MESIAL GROOVE

Instruments:	bin angle chisel hatchet
Form:	meets unprepared tooth surface at 90^0
Extension:	includes proximal contact to cleansable area terminates lingually to facioproximal line angle, if possible

B

FACIAL CUSP BEVELED (CONCAVE)

Instrument:	tapered round-end diamond
Depth:	1.0 mm clearance with opposing tooth

C

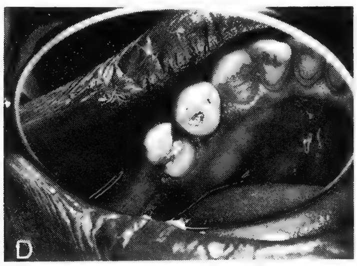


FIGURE 5–19

A, Procedures for forming mesial flair.
B, Procedures for forming facial flair.
C, Procedures for beveling facial cusp.
D, Flaring of the facial wall of the mesial groove with a hatchet.
E, Occlusal view of flared mesial aspect of distobuccal modification groove.
F, Concave facial bevel placed with tip of diamond instrument.

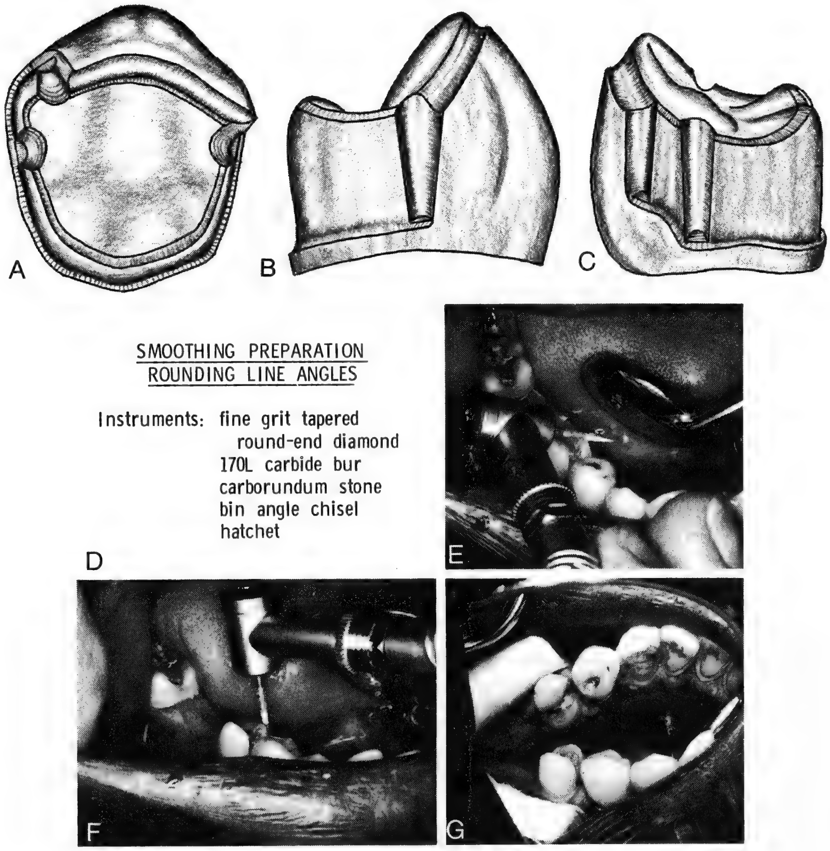


FIGURE 5–20

A, Occlusal view of completed preparation.
B, Mesial view of completed preparation.
C, Distal view of completed preparation.
D, Procedures for smoothing preparation and rounding line angles.
E, Rounding line angles.
F, Smoothing the axial wall.
G, Finished preparation.

facial occlusal contacts by 0.5 mm (Fig. 5–19C, F). To achieve adequate thickness, the bevel is given a concave form. It is formed with the tip of a round-end diamond creating an occlusal clearance of 1.0 mm. The bevel not only allows an adequate occlusal thickness of metal over the facial cusp but also aids in resisting lingual displacement of the restoration.

Final Smoothing

As the final procedure, the preparation is smoothed, the margins further refined as necessary, and the line angles rounded using a round-end fine-grit finishing diamond of the same size and shape as before or the hand instruments already mentioned (Fig. 5–20).

THE MANDIBULAR MOLAR PARTIAL VENEER CROWN PREPARATION

The partial veneer preparation for a mandibular molar is like that for a maxillary molar except that a concave bevel, as is used for a mandibular premolar, is placed on the facial cusps. The instrumentation and order of procedures are identical to those used for the same steps in the procedures previously described.

6

The Anterior Partial Veneer Crown

Because of the relative ease with which a tooth can be prepared for a metal-ceramic restoration and the high priority many dentists and patients place on esthetics, the anterior partial veneer restoration has lost popularity. However, when teeth are intact, or nearly so, and are in normal alignment, it is quite possible to create acceptable esthetic results with a partial veneer crown. Successful use of this restoration requires the development of fine skills and the ability to educate patients as to the benefits of a conservative restoration. The achievement of a result that is both esthetic and conservative easily justifies the use of this restoration.

ADVANTAGES

The advantages of conservation, the favorable periodontal response, and the esthetic qualities attributed to the posterior partial veneer crown apply to this restoration as well (see Chapter 5).

DISADVANTAGES

The same disadvantages inherent in the posterior partial veneer crown are also true of anterior partial veneers. In addition, anterior teeth, particularly incisors, are quite thin, a characteristic that may cause the tooth to become darker when the restoration is cemented. This problem may be mitigated by the selection of a luting cement with color characteristics that enhance the color of the tooth. Also, the thinness of anterior teeth makes retention for the partial veneer restoration difficult because of the limited bulk for placing proximal retention boxes or grooves.

INDICATIONS

The partial veneer crown is indicated on anterior teeth that have the following characteristics:

1. The coronal tooth structure is intact or minimally restored.
2. A normal coronal form exists, that is, not a conical form.
3. There is average or greater than average crown length.

When the restoration is to be used as a retainer for a fixed prosthesis, the following also are considerations:

1. The abutment teeth are in normal axial alignment.
2. The lever arm is relatively short.
3. There are average or below average occlusal forces.

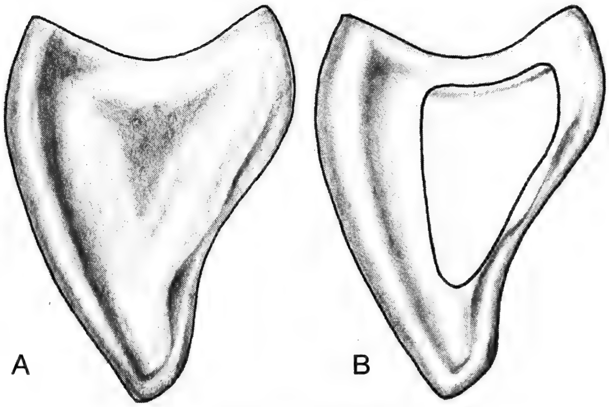
THE MAXILLARY ANTERIOR PARTIAL VENEER CROWN PREPARATION

Although the maxillary incisors and canines differ considerably morphologically, the principles applied in the preparation of both types of teeth are the same for partial veneer crowns.

Proximal Reduction

The first step is the reduction of the proximal surfaces using a small-diameter tapered round-end diamond instrument* with coarse or medium grit size (Fig. 6–1). The pulpal depth of the cut may vary from 0.3 to 0.5 mm, and preferably the reduction terminates supragingivally on enamel as a chamfer. However, since retention is often a major consideration, it is frequently necessary to extend the preparation subgingivally to gain maximal length. The facial extent of the cut should terminate midway through the proximal contact, leaving a vertical lip of enamel that extends proximally and remains in contact with the approximating tooth when

*Blu-White 1/2 DT, Teledyne Densco, Denver, CO 80207.



PROXIMAL REDUCTION

Instrument:	tapered round-end diamond
Form:	tapered occlusally 3 to 5°
	terminates as a chamfer
Depth:	0.3 to 0.5 mm cervically
	related to tooth form, axial alignment, and preparation length
Extension:	length adequate for retention
	ideally terminates on enamel
	ideally terminates supragingivally

C

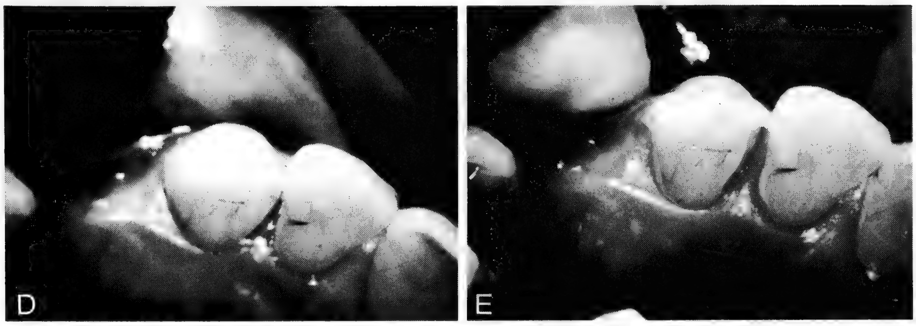


FIGURE 6–1

A, Maxillary canine.
B, Proximal reduction.
C, Procedures for proximal reduction.
D, Maxillary canine viewed incisally.
E, Proximal surfaces reduced.

one is present. When there is no adjacent tooth for reference, extra care should be taken to avoid facial overextension.

Lingual Reduction—Cingulum

The two proximal cuts are joined by reducing the vertical portion of the cingulum by using the same tapered round-end diamond instrument as for the proximal reduction. A vertical surface is produced that converges at 3 to 5 degrees and is compatible with the path of insertion. The cut should terminate on enamel and form a chamfer having a depth of 0.3 to 0.5 mm (Fig. 6–2).

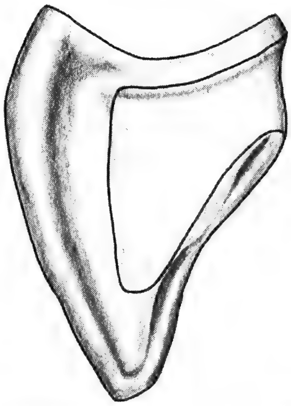
Incisal Reduction

In preparation for placing the incisal groove, the incisal edge is beveled using a 170L carbide bur (Fig. 6–3). The bevel is angled lingually at about 60 degrees to the incisal two-thirds of the facial surface or approximately 45 degrees to the tooth's long axis. The bevel should be flat labiolingually, terminating facially at the labioincisal line angle. If the tooth being prepared is a canine, this step involves placing two distinct bevels, one for each incisal arm. When the tooth is an incisor, one bevel is formed. In any case, mesiodistally the anatomic form is followed.

Lingual Reduction—Occlusion

The remainder of the lingual surface is reduced to clear centric occlusion (Fig. 6–4). This is done by using a round-edge wheel* or a football-shaped† diamond instrument, with reduction carried out to a uniform depth of 1.0 following the anatomic concavity of the

*Two Striper number 860F, Premier Dental Products Co., Philadelphia, PA 19107.
†Number 368, Brasseler USA, Savannah, GA 31405.



A

LINGUAL REDUCTION
(CINGULUM)

Instrument:	tapered round-end diamond
Form:	terminates in chamfer
Depth:	0.3 to 0.5 mm
Extension:	joins proximal reduction length adequate for retention ideally terminates on enamel ideally terminates supragingivally

B

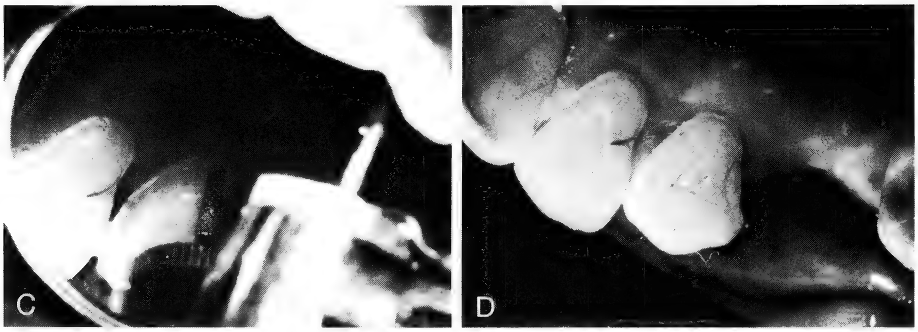
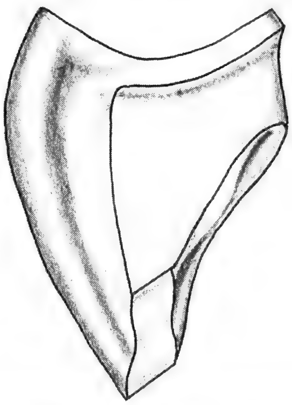


FIGURE 6–2

A, Lingual reduction—cingulum.
B, Procedures for lingual reduction—cingulum.
C, Diamond instrument used to reduce lingual surface cervical to cingulum.
D, Lingual chamfer formed.



A

INCISAL REDUCTION

Instruments:	170L carbide bur 56L or 57L carbide bur
Form:	flat bevel
Angulation:	60° relative to incisal 2/3 of facial surface 45° relative to long axis
Extension:	to labioincisal line angle

B

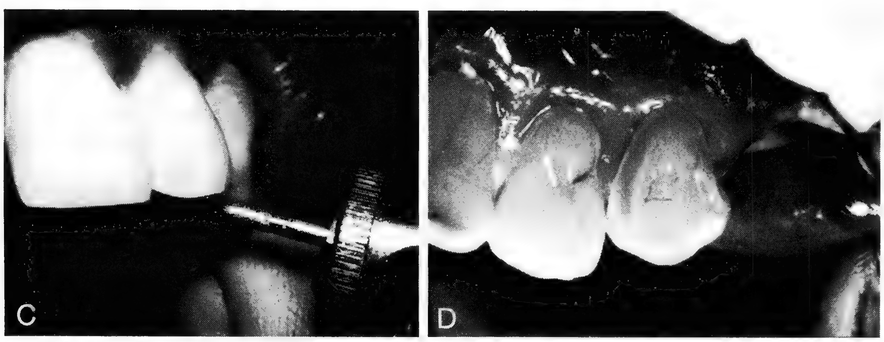


FIGURE 6–3

A, Incisal reduction.
B, Procedures for incised reduction.
C, Diamond instrument held at approximately 60 degrees relative to incisal two-thirds of facial surface.
D, Incisal edge reduced.

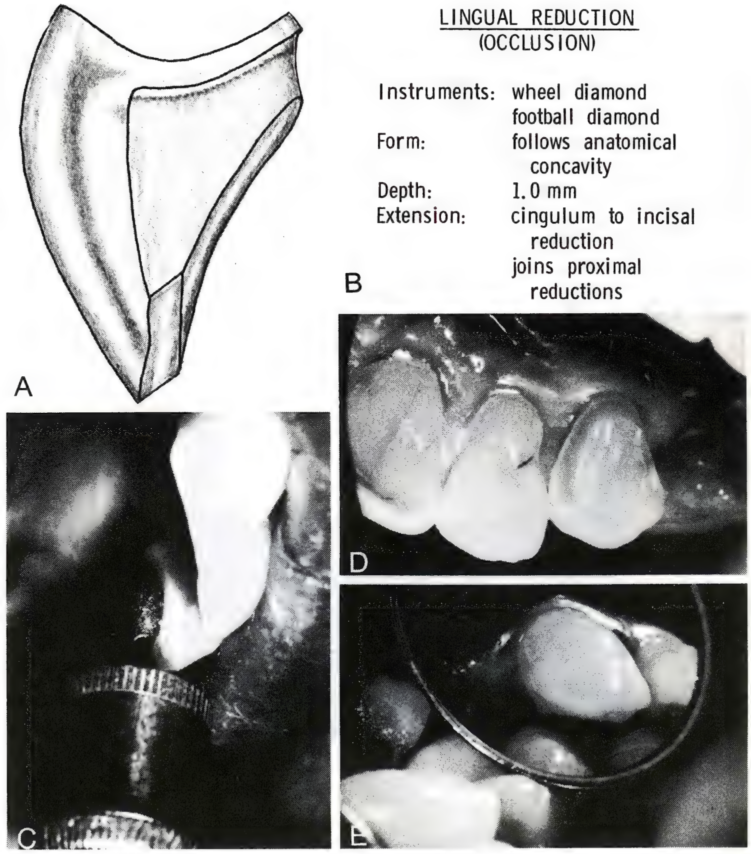


FIGURE 6–4

A, Lingual reduction—occlusion.
B, Procedures for lingual reduction—occlusion.
C, Football-shaped diamond instrument used for lingual reduction.
D, Lingual surface reduced.
E, Clearance with opposing tooth being checked.

lingual surface. Care must be taken to avoid overreduction at the linguoincisal line angle in order to retain enough bulk for placing the incisal groove.

Incisal Groove

Next, an incisal groove is formed to join the two proximal retentive grooves (Fig. 6–5). Its main function, particularly on maxillary teeth, is to increase resistance form by providing bulk, which prevents distortion of the restoration by functional forces. The groove is placed with a 56L or 57L carbide bur and therefore forms a 90-degree angle. The depth of the groove is located one-third of the distance from the lingual extent of the incisal reduction and should be in dentin. The groove's inclination faciolingually is such that an angle of 90 degrees is formed with the reduced lingual surface. The groove is 0.3 to 0.5 mm deep at its lingual extent and tapers out facially, with no additional reduction being made at the labioincisal line angle.

Proximal Grooves

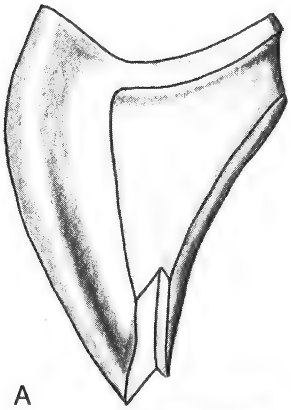
The mesial and distal proximal grooves provide most of the retention form for the anterior partial veneer crown. They are made with a 170L carbide bur and converge at an angle of 3 to 5 degrees. The grooves are located in the facial one-half of the crown and pass through the lingual portion of the proximal contact area. They are made parallel to the path of insertion, which ideally is parallel to the incisal two-thirds of the labial surface. The grooves should be 0.3 to 0.5 mm deep and terminate cervically at the beginning of the chamfer. The faciolingual width should be about 1.0 mm (Fig. 6–6).

Cingulum Ledge and Pinhole

The morphology of anterior teeth limits the degree of retention that can be achieved in a partial veneer preparation. Therefore, most, if not all, anterior teeth require augmentation of the retention form by the placement of at least one pinhole. The first step is to place a ledge in the center of the cingulum using a 56L or 57L carbide bur. The ledge is half-moon–shaped and approximately 2.0 mm wide mesiodistally and 1.0 mm wide facioligually. The pinhole is centered in the ledge. It is produced by first creating a pilot hole with a number one-half round carbide bur and then completed with a number 700 tapered fissure carbide bur. Its depth is 1.5 to 2.0 mm (Fig. 6–7).

Facial Flare of Proximal Grooves

The facial aspect of each groove is flared facially using a suitably sized binangle chisel or hatchet (Fig. 6–8).



A

B

INCISAL GROOVE

Instrument:	56L or 57L carbide bur
Form:	90° angle
Location:	1/3 from lingual extent of incisal reduction to labioincisal angle
Angulation:	90° relative to lingual surface
Depth:	0.3 to 0.5 mm lingually tapers out facially
Extension:	joins proximal reductions

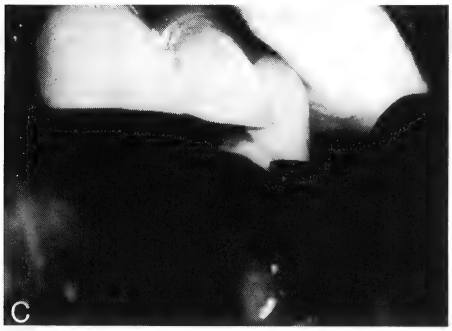
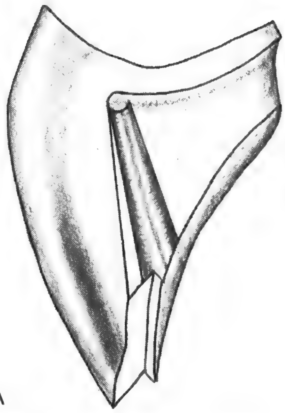


FIGURE 6–5

A, Incisal groove.
B, Procedures for forming incisal groove.
C, Incisal groove formed with 56L carbide bur.



A

B

PROXIMAL GROOVES

Instrument:	170L carbide bur
Form:	tapered occlusally 3 to 5°
Location:	in facial 1/2 of crown lingual aspect of proximal contact
Angulation:	parallel to path of insertion parallel to incisal 2/3 of facial surface
Depth:	0.3 to 0.5 mm cervically after proximal reduction
Width:	1.0 mm minimum
Extension:	to beginning of chamfer

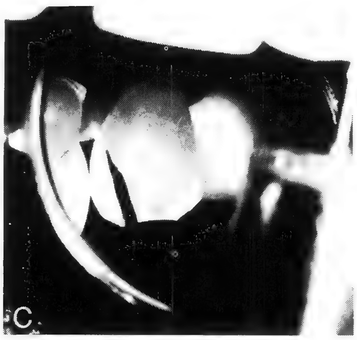


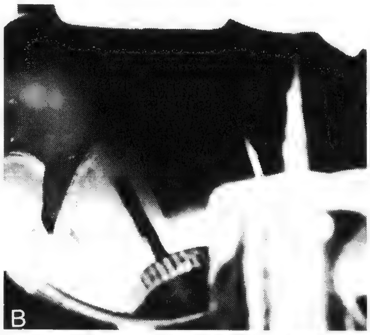
FIGURE 6–6

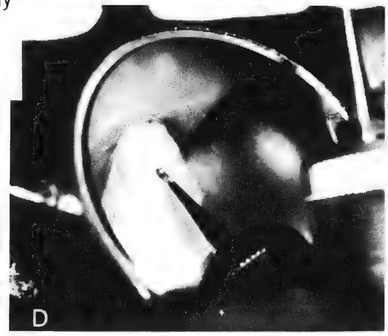
A, Proximal grooves.
B, Procedures for forming proximal grooves.
C, Mesial groove formed with 170L bur.
D, Distal grooved aligned with mesial groove.

CINGULUM LEDGE & PINHOLE

Instruments:	56L or 57L carbide bur ½ carbide bur 700 carbide bur
Location:	ledge in center of cingulum pinhole in center of ledge
Angulation:	parallel to path of insertion and proximal grooves
Depth:	1.5 to 2.0 mm pinhole
Width:	2.0 mm ledge lingually
Extension:	1.0 mm minimum facial extension to ledge

A





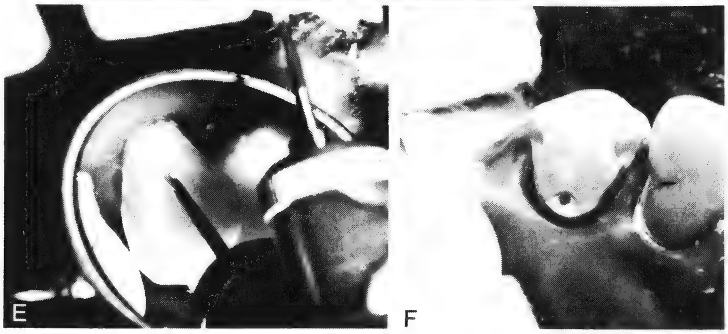


FIGURE 6–7

A, Procedures for forming cingulum ledge and pinhole.
B, Formation of ledge using 56L carbide bur.
C, Ledge extended facially into dentin.
D, Number ½ round bur used to create pilot hole.
E, Tapered pinhole formed with number 700 bur.
F, Ledge and pinhole established.

FACIAL FLARE OF PROXIMAL GROOVES

Instruments:	bin angle chisel hatchet
Form:	meet unprepared tooth surface at 90°
Extension:	include proximal contacts to cleansable area terminates lingual to facioproximal line angle if possible

A

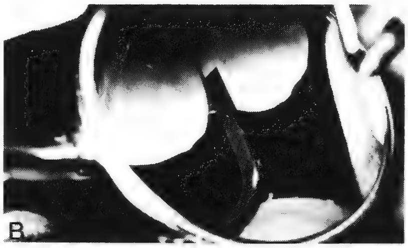


FIGURE 6–8

A, Procedures for forming facial flare of proximal grooves.
B, Flaring the facial wall of mesial groove with hatchet.
C, Flare is extended just facial to proximal contact.

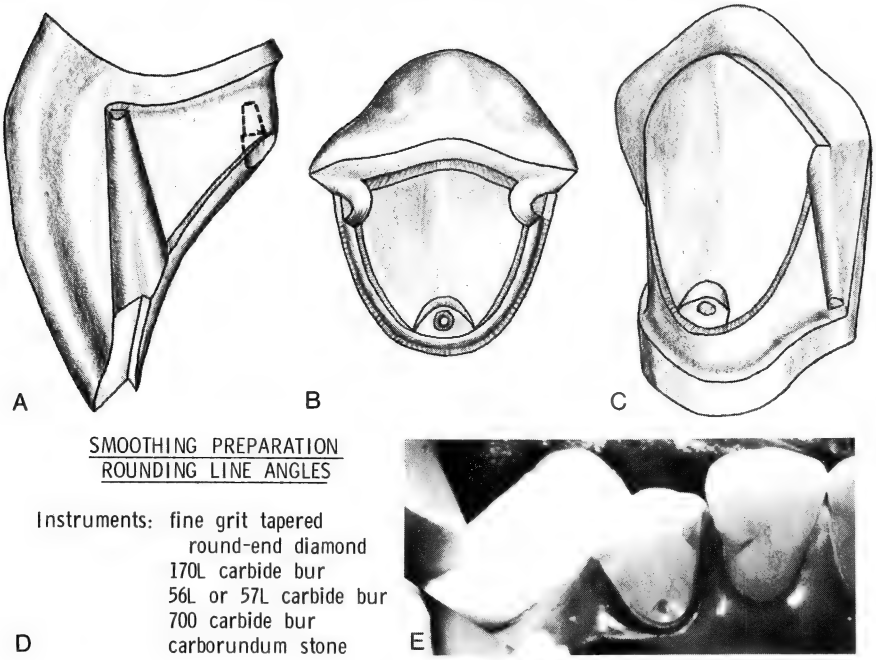


FIGURE 6–9
A, Proximal view of finished preparation.
B, Incisal view.
C, Mesiolingual view.
D, Procedures for smoothing preparation and rounding line angles.
E, Completed clinical preparation.

This procedure smoothes the facial wall of the groove, eliminates the lip of enamel left in contact with the adjacent tooth, and creates a facial margin that meets the unprepared tooth structure at approximately a 90-degree angle. The flare is extended facially into a cleansable area, but for esthetic reasons it terminates lingual to the facioproximal line angles.

Smoothing of the Preparation and Rounding of Line Angles

Refinement and smoothing of the preparation and rounding of the line angles is accomplished by using a fine-grit version of the diamond instrument employed to make the initial cuts or with the same carbide instruments used previously (Fig. 6–9). Carborundum stones may also be used where these are appropriate. Smoothness of the preparation aids in the fit of the casting, but polishing a preparation is neither necessary nor desirable.

Esthetic Considerations

Since optimal esthetic results with anterior partial veneer crowns are achieved only by strict observance of certain principles, it seems appropriate to restate these principles here:

1. Labioproximal finish lines must not be extended to the line angles, or an unsightly display of metal will result.

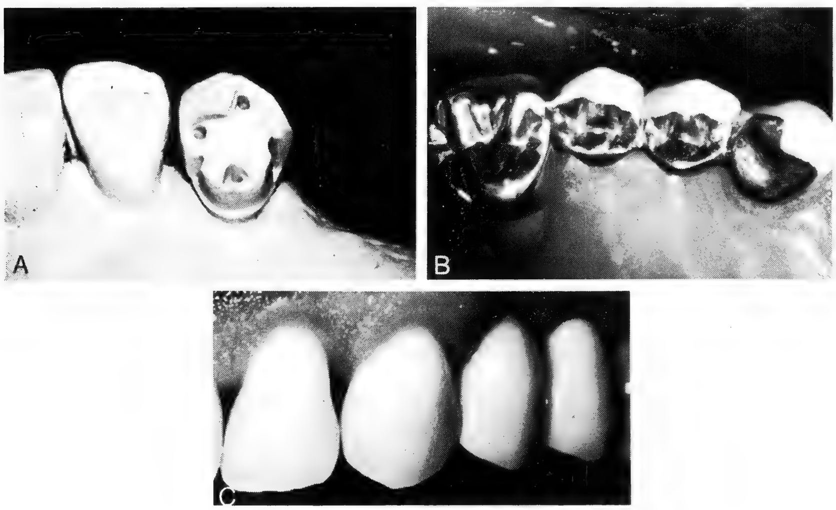


FIGURE 6–10
A, Maxillary canine preparation with mesial groove located lingual to proximal contact and three auxiliary pinholes.
B, Cemented prosthesis.
C, Facial view of prosthesis.

2. The incisal aspect of the lingual surface must not be excessively reduced; otherwise, the restoration will show through the labial enamel, giving the tooth an unnaturally gray appearance.
3. Incisal reduction must be minimized to avoid the display of metal at the labioincisal line angle.

When the occlusion is favorable, involvement of the mesial incisal arm of the maxillary canine may be avoided in order to improve the esthetic result. This modification of the partial veneer preparation may also include the placement of a mesial groove located lingual to the proximal contact, thereby keeping the entire visible mesial aspect of the tooth intact (Fig. 6–10). The use of pinholes to augment the retention form of this modified partial veneer preparation is advisable.

It is vitally important that no excursive movement cross the margin between the restoration and the tooth. This would likely burnish the metal and cause marginal distortion and early failure from leakage or loss of retention.

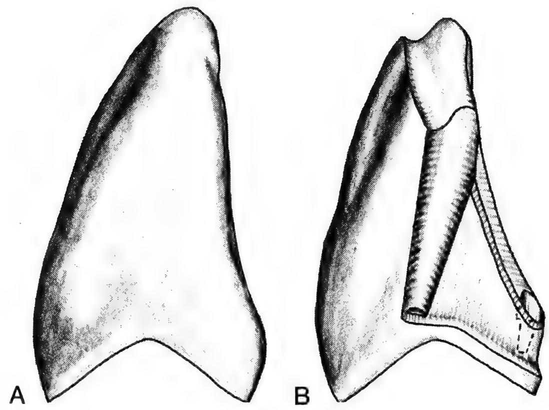


FIGURE 6–11

A, Mandibular canine.
B, Partial veneer crown preparation.

THE MANDIBULAR ANTERIOR PARTIAL VENEER CROWN PREPARATION

The successful use of the partial veneer crown on mandibular anterior teeth requires the acceptance of esthetic results that are less than ideal. Such results are caused by the necessity of covering the incisal edge with metal in order to protect the prepared tooth from the forces of the occlusion. Failure to provide adequate protection increases the possibility of chipping and fracture of the unprotected incisal edge. Since worn mandibular incisal edges usually slant labially, significant amounts of gold are unavoidably displayed. However, there may be occasions when mechanical requirements outweigh esthetic considerations; for example, the teeth to be restored may occlude with metallic restorations so that the metal-ceramic restoration is undesirable because of its potentially abrasive nature.

The mandibular preparation is essentially the same as that for maxillary teeth except that the incisal groove is placed on the facial surface instead of lingually and must include all of the incisal aspect of the tooth that is in occlusion (Fig. 6–11). Because of the smaller size of mandibular incisors, smaller instruments may need to be employed when these teeth are prepared for partial veneer crowns.

7

The Pinledge Retainer

Of all the retainers used with anterior fixed prostheses, the pinledge has the greatest potential for optimal esthetics. The preservation of facial enamel is always an asset to appearance and allows the display of metal to be kept to a minimum or to be eliminated altogether in certain situations.

Retention for the conventional pinledge design comes solely from a series of three or more pins. Its resistance form is provided by indentations and ledges, which allow the development of a bulk of metal for reinforcement against distortion. Modifications of the preparations may include one or more grooves, which create a hybrid preparation having some of the characteristics of both the pinledge retainer and the partial veneer crown.

While the retention attainable with a pinledge can be quite adequate under many clinical situations, its resistance against twisting or rotational forces is not as great as that obtained with other retainers. This is true because the pinledge involves somewhat less than 50 per cent of the coronal area of the tooth. Even under ideal circumstances, its lack of bulk and size limits its rigidity and therefore its resistance to distortion. While there may be some choice as to the type of metal to be used for other retainers, the pinledge must be cast from a type IV gold or an alloy with comparable physical properties in order to optimize both hardness and rigidity.

ADVANTAGES

Pinledge retainers have the following advantages when compared with other more inclusive restorations: (1) minimal tooth structure is lost; (2) optimal periodontal response is achieved because most, if not all, of the finishing line is placed supragingivally; and (3) optimal esthetic results can be attained.

DISADVANTAGES

There are three main disadvantages attributed to the pinledge: (1) it has less resistance to distortion than any other adequately executed retainer; (2) while it is a restoration with a relatively simple design, it must be executed with greater than average skill and care; and (3) largely because of the first two factors, its application is rather limited.

INDICATIONS

The pinledge retainer is indicated on anterior teeth under the following circumstances:

1. The coronal tooth structure is intact or nearly so.
2. Normal coronal form is present.
3. The crown of the tooth is of average length or longer.
4. The tooth has average or greater labiolingual thickness in the incisal one-half of the crown.
5. The abutment teeth are in normal alignment or very nearly so.

Certain canines with a very pointed form and short proximal surfaces can successfully be prepared for a pinledge when a partial veneer or even a full-coverage preparation would lack sufficient retention because of the shortness of the proximal surfaces.

Also, the pinledge restoration, or a modification of it, may be useful as a restoration to aid in the support of a removable partial denture.

CONTRAINDICATIONS

The pinledge is usually contraindicated under the following conditions:

1. When caries or a restoration extends past the normal outline of the preparation or when either of these conditions would involve an area in which a retentive pinhole must be placed.
2. The crown of the tooth exhibits abnormal form or other developmental defects.
3. The crown of the tooth is so thin labiolingually that the preparation would allow the retainer to show through the labial enamel, or the labial enamel would be left unsupported by dentin.
4. Conditions exist that could cause excessive torsional force to be applied to the retainer, such as with

abnormal abutment alignment, production of a lever arm by the prosthesis, or excessive span length.

THE PINLEDGE RETAINER PREPARATION

As has been indicated previously, the use of the pinledge is limited to the 12 anterior teeth. The preparation involves the proximal surface adjacent to the edentulous space to be restored, covers most of the lingual surface, and usually includes most of the incisal edge. The preparation is described in step-by-step detail for the maxillary incisor. Modifications useful for canines and mandibular incisors are discussed later.

Proximal Reduction

The initial step is the reduction of the proximal surface adjacent to the edentulous space (Fig. 7–1). This procedure makes room for the solder joint, which connects the retainer to the pontic. Reduction is accomplished by using a 170L carbide bur. The cut should be flat on both planes so as to involve the least amount of tooth structure. Incisocervically, the cut must be compatible with the selected path of insertion, but it converges lingually at an angle of about 45 degrees to the proximal surface. This convergence provides for the bulk of metal needed to achieve rigidity between the proximal and lingual portions of the restoration. As is true for anterior partial veneer crowns, the ideal path of insertion for the pinledge is parallel to the incisal two-thirds of the labial surface. The cut is elliptic in outline and extends facially to include the proximal contact, but only far enough to barely reach a cleansable area. Further labial extension jeopardizes the esthetic result.

Lingual Reduction of Cingulum and Marginal Ridge

This step involves the reduction of the vertical portion of the cingulum to form the cervical finishing line and the reduction of the medial aspect of the lingual marginal ridge on the side opposite the edentulous space to form the finishing line for that portion of the preparation (Fig. 7–2). This cut is made with a tapered round-end medium-grit diamond instrument.* Its cervical extension terminates on enamel, preferably in a supragingival location. Proximally, the reduction involves the medial one-half of the marginal ridge and terminates at its lingual crest. The cut extends from the cervical aspect of the original proximal reduction to the incisal edge on the opposite side of the tooth, having a depth of 0.3 to 0.5 mm. Thus the lingual outline of the preparation has been established.

Incisal Reduction

To provide protection for the incisal enamel against the force of occlusion, the incisal edge is reduced to allow a thickness of metal in that area. This reduction is made with a 170L, 56L, or 57L carbide bur to form a flat area at an angle of about 60 degrees with the incisal

*Blue-White 1/2 DT, Teledyne Densco, Denver, CO 80207.

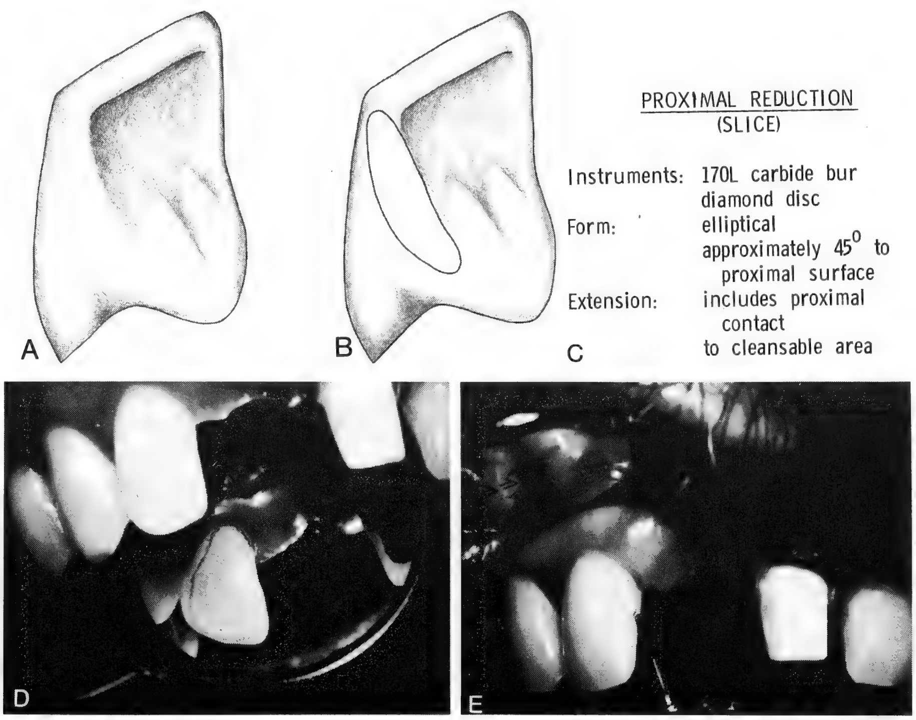
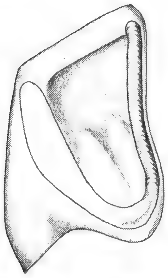


FIGURE 7–1
A, Maxillary central incisor.
B, Proximal reduction.
C, Procedures for proximal reduction.
D, Pinledge preparation outlined in pencil.
E, 169L carbide bur used for proximal reduction.



A

LINGUAL REDUCTION
(CINGULUM)
MARGINAL RIDGE REDUCTION

Instrument:	tapered round-end diamond
Form:	chamfer
Depth:	0.3 to 0.5 mm
Extension:	slightly above cervical line
	center of marginal ridge

B

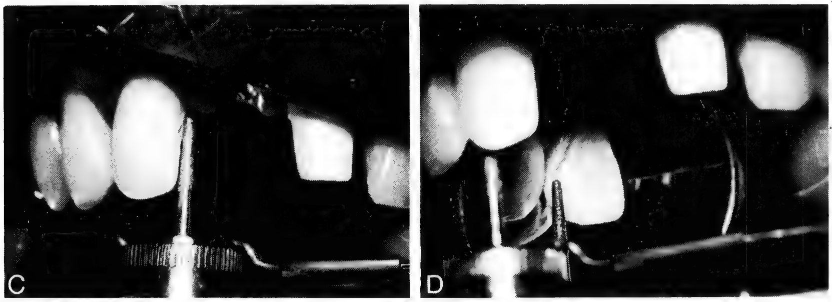


FIGURE 7–2

A, Cingulum and marginal ridge reduction.
B, Procedures for lingual and marginal ridge reduction.
C, Round-end diamond instrument aligned with reduced proximal surface.
D, Tip of instrument used to reduce marginal ridge.

two-thirds of the labial surface. This, in most cases, would be about 45 degrees relative to the long axis of the tooth. The reduction extends to the labioincisal line angle and mesiodistally connects the proximal slice with the reduction already made on the opposite marginal ridge (Fig. 7–3).

Lingual Reduction—Occlusion

The remaining uncut portion of the lingual surface is now reduced with either a medium-grit wheel* or a football-shaped† diamond instrument. The reduction follows the anatomic form of the lingual concavity to a depth of 0.5 to 1.0 mm (Fig. 7–4).

Ledges

Using a 56L or 57L carbide bur, two ledges are formed (Fig. 7–5). These ledges are made parallel to the incisal edge and to each other. The incisally located ledge is placed about one-fourth of the distance from the incisal edge to the cervical finishing line, while the one located cervically is formed about one-eighth of the distance from the cervical finishing line to the incisal edge. The instrument is held parallel to the incisal two-thirds of the facial surface to create a ledge that is 0.3 to 0.5 mm in width, depending on the thickness of the tooth. The

*Two striper number 860F, Premier Dental Products, Philadelphia, PA 19107.
†Number 368, Brasseler USA, Savannah, GA 31405.

INCISAL REDUCTION

Instruments:	170L carbide bur
	56L or 57L carbide bur
Form:	flat bevel
Angulation:	60° relative to incisal 2/3 of facial surface
	45° relative to long axis
Extension:	to labioincisal line angle

A

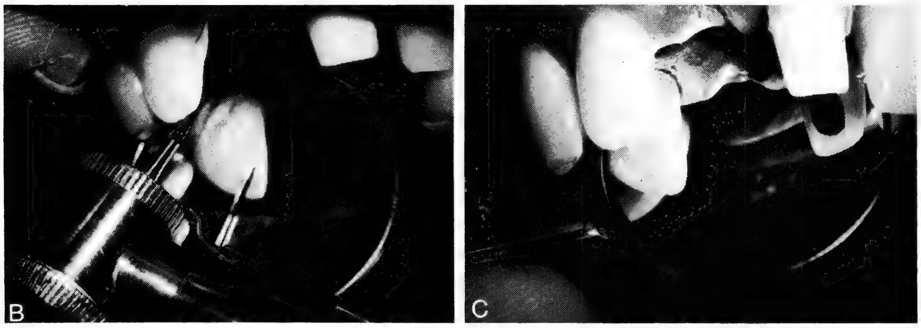
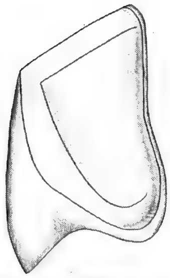


FIGURE 7–3.

A, Procedures for incisal reduction.
B, 170L carbide bur held at 60 degrees relative to incisal two-thirds of labial surface.
C, Reduced incisal edge.



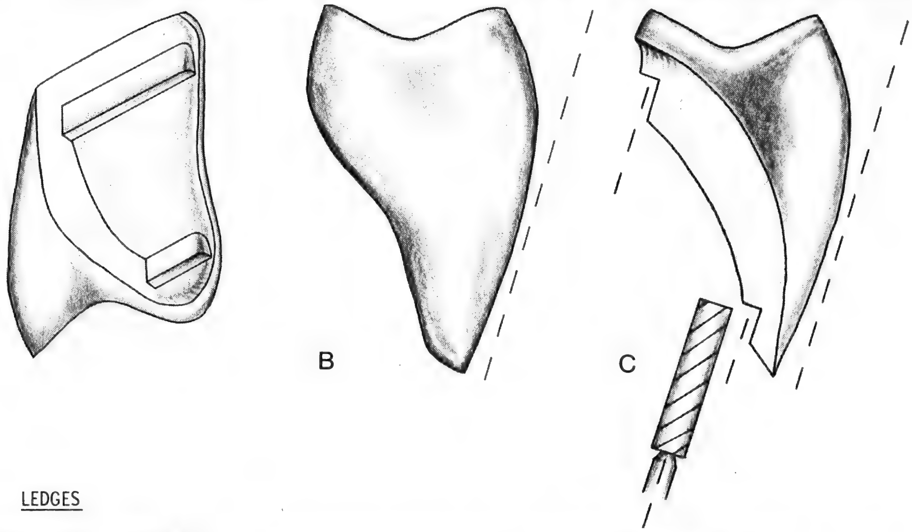
LINGUAL REDUCTION
(OCCLUSION)

Instruments: wheel diamond
football diamond
Form: follows anatomical concavity
Depth: 0.5 mm minimum
Extension: marginal ridge to proximal slice
cingulum to incisal reduction

B

FIGURE 7–4

A, Lingual reduction (occlusion).
B, Procedures for lingual reduction—occlusion.
C, Wheel diamond used for reduction.
D, Reduced lingual surface.



LEDGES

Instrument: 56L or 57L carbide bur
Location: 1/8 and 3/4 points between cervical chamfer and incisal edge
Angulation: facial wall parallel to incisal 2/3 of facial surface
cervical wall parallel to incisal edge
Depth: 0.3 to 0.5 mm
Extension: proximal slice to marginal ridge chamfer

D

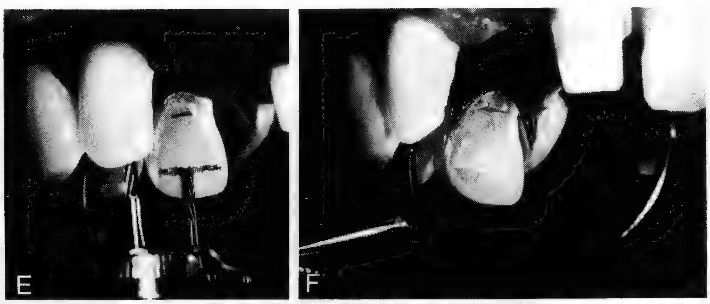


FIGURE 7–5

A, Ledges.
B, Line paralleling incisal two-thirds of facial surface.
C, Ledges formed so facial wall is parallel to incisal two-thirds of facial surface.
D, Procedures for forming ledges.
E, Location of ledges marked in pencil.
F, Ledges formed approximately parallel to incisal edge.

ledges extend from the center of the chamfer finishing line in the marginal ridge to the reduced proximal surface on the edentulous side. The ledges provide rigidity in the casting, create flat surfaces in which pinholes can be drilled, and provide for positive seating of the casting.

Indentations

These features in the preparation serve to provide additional space in which to locate the pinholes and to create points of stabilization for the casting. There are three indentations, two located on the incisal ledge and one on the cervical ledge. They are made with a 56L or 57L carbide bur and are located 0.5 to 1.0 mm medial to the lingual outline form of the preparation. The vertical walls formed must be made parallel to the path of insertion (parallel with the incisal two-thirds of the labial surface) and parallel to each other. Each has a depth of 0.3 to 0.5 mm. Thus the total space available for pinhole placement is from 0.6 to 1.0 mm in labiolingual dimensions. The incisal indentations are spaced as far apart as possible, not only to maximize stability but also to insure that the retentive pinholes may be placed so as to avoid injury to the dental pulp (Fig. 7–6).

Pinholes

The last major step in the pinledge preparation is placement of the three pinholes. They are placed using a number ½ round bur to drill a pilot hole to proper depth, followed by a 700 carbide bur to produce a tapered hole (Fig. 7–7). Each pinhole is centered in its indentation, made parallel to the incisal two-thirds of the labial surface, and cut to a depth of 1.5 to 2.0 mm. Centering the holes is very important, since placement too close to the lingual aspect of the ledge may allow fracture of thin tooth structure to occur when the casting is trial-inserted. Likewise, close labial proximity may cause the metal to show through the enamel.

Smoothing Preparation

The preparation is finalized (Fig. 7–8) by removing any roughness with fine-grit finishing diamonds corresponding in size and shape to those used for the initial cuts or by using a Carborundum stone having a similar size and shape. Cuts originally made using burs can be refined using the same instruments. It is particularly important that a pinledge preparation be very smooth in order to assure unimpeded seating of the restoration

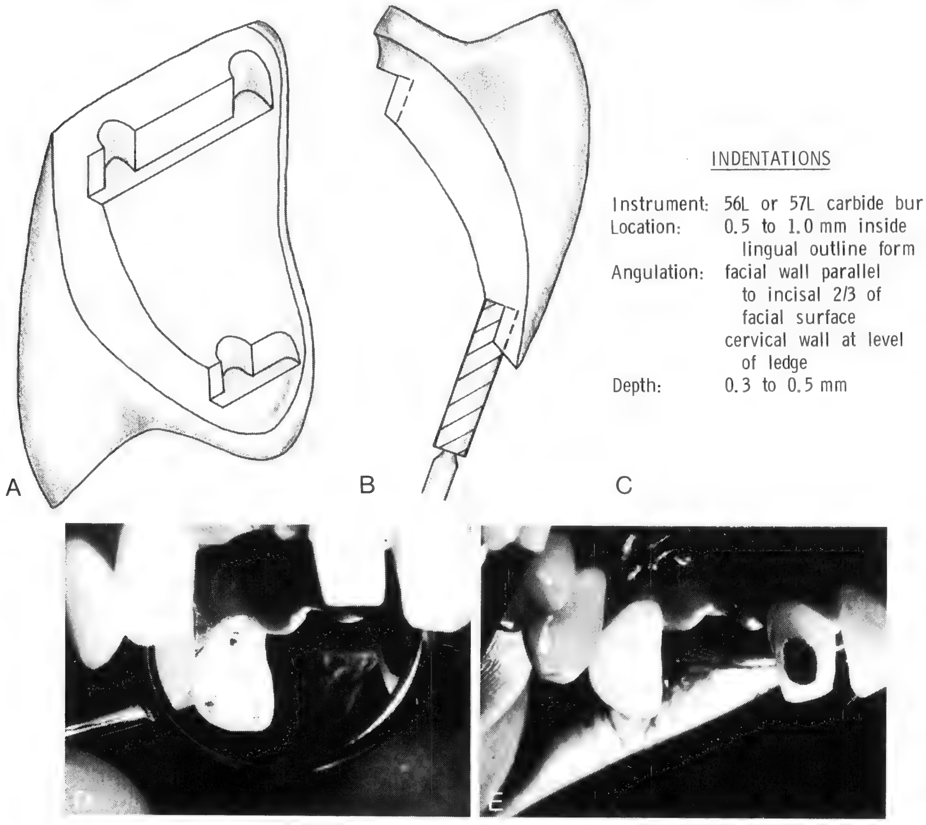
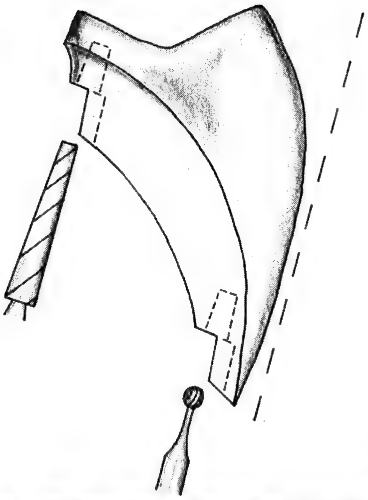


FIGURE 7–6

A, Indentations.
B, Alignment of carbide bur with incisal two-thirds of labial surface.
C, Procedures for forming indentations.
D, Indentation locations marked with pencil.
E, Indentations formed.



A

B

PINHOLES

Instruments:	1/2 carbide bur
	700 carbide bur
Location:	centered in indentation
Angulation:	parallel to incisal 2/3 of facial surface
Depth:	1.5 to 2.0 mm

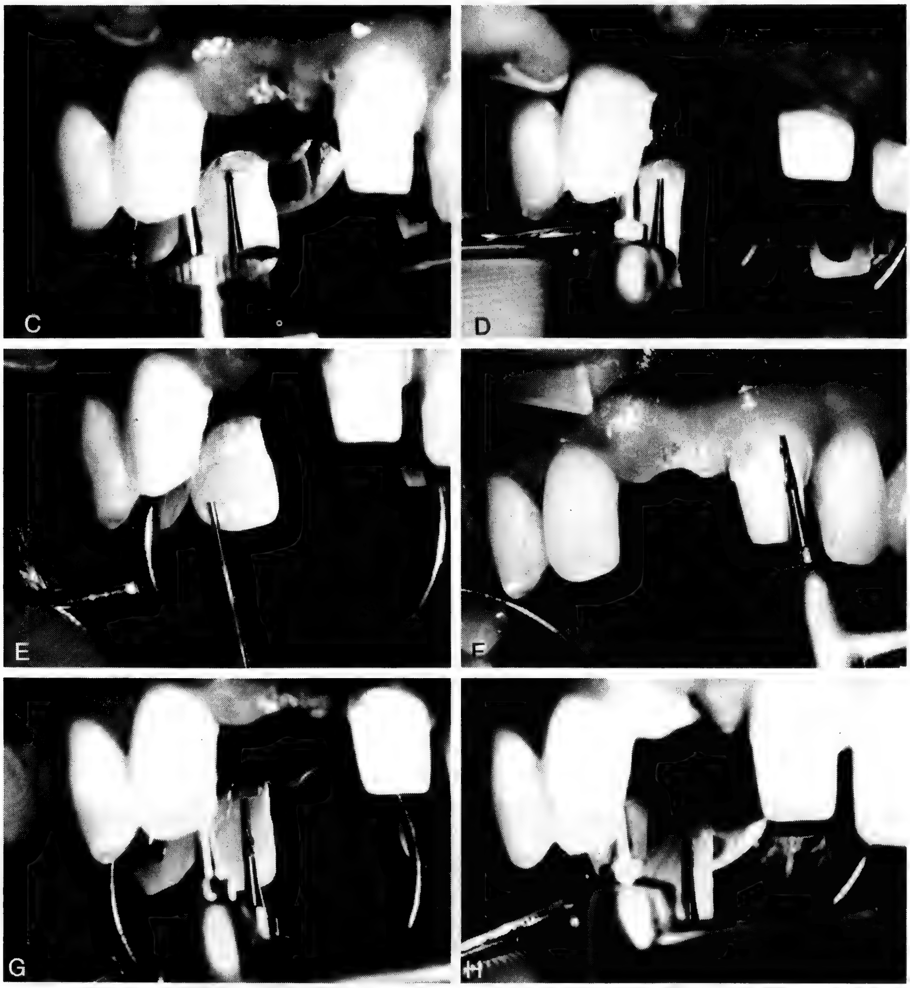


FIGURE 7–7

A, Pinholes formed parallel with incisal two-thirds of labial surface.
B, Procedures for forming pinholes.
C, Number ½ round bur aligned for establishing pilot hole.
D, Drilling cervical hole.
E, Measuring depth with periodontal probe.
F, Number 700 tapered carbide bur aligned with path of insertion.
G, Bur moved to pilot hole location.
H, Pilot hole formed into tapered pinhole.

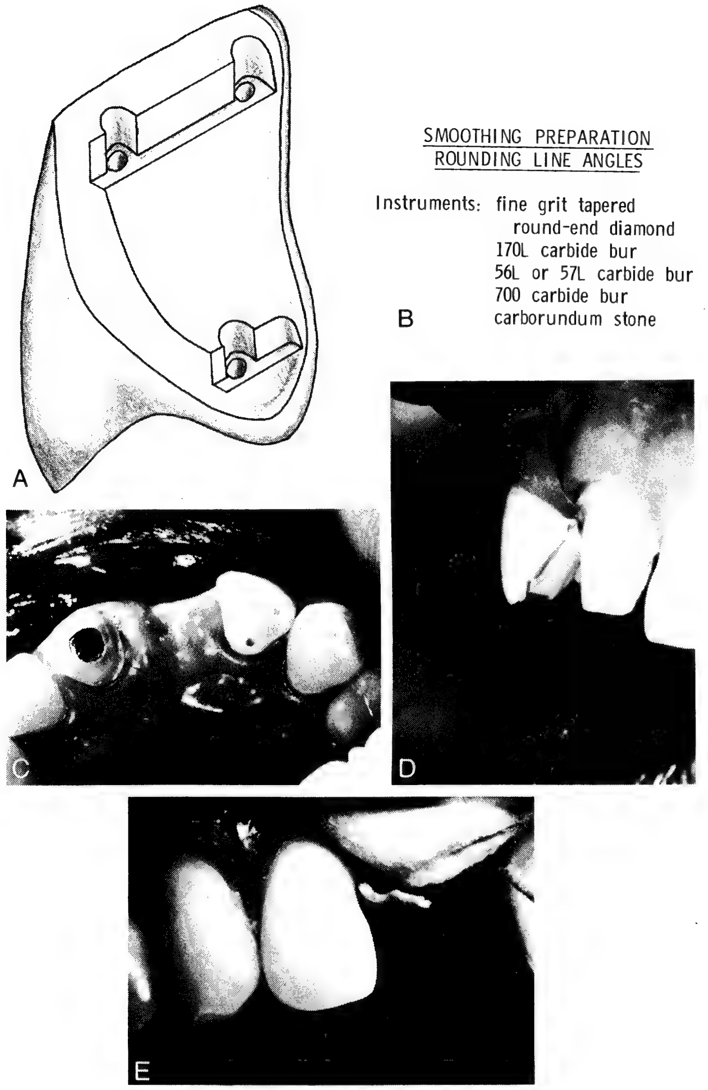


FIGURE 7–8

A, Completed pinledge preparation.
B, Procedures for smoothing preparation and rounding line angles.
C, Incisal view.
D, Mesial view.
E, Facial view.

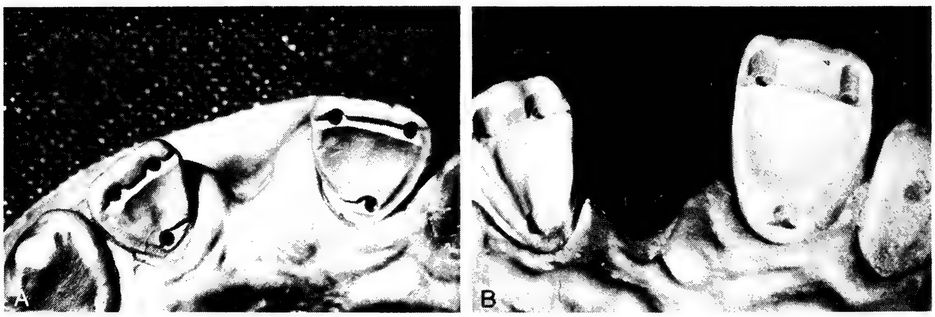


FIGURE 7–9

A, Working cast of two pinledge preparations.
B, Lingual view.

FIGURE 7–10 Additional pinholes placed in canine and central incisor abutment preparations.

(Fig. 7–9). Binding caused by roughness is difficult to eliminate in such an intricate casting without seriously affecting its fit and thus its potential for success.

The Canine Preparation

The pinledge preparation for the maxillary canine is essentially the same as that for the incisor, except that when the incisal ledge is formed it is made to follow the incisal outline, which generally has a V-shaped outline.

Pinledge Preparation Modifications

The pinledge design may be altered advantageously to meet special situations. These modifications may include the use of additional pins or a proximal retentive groove or the noninvolvement of all or part of the incisal edge.

Additional Pins

When maximal retention is sought, additional pins may be helpful. An extra pinhole can be added cervically or on the side away from the edentulous space, midway between the incisal pin and the cervical pin (Fig. 7–10).

Proximal Groove Modification

In a number of circumstances a proximal groove is indicated as an alteration to a pinledge preparation (Fig. 7–11). An example of one circumstance is when there is the need for greater rigidity, particularly in the connector area, as may be desirable for use with a longer-span fixed prosthesis. Another such situation is when a pinledge is being considered for use on a canine as the anterior retainer for a short-span posterior bridge. Still another use of the proximal groove is with pin-retained restorations used to modify anterior teeth for the support of removable partial prostheses.

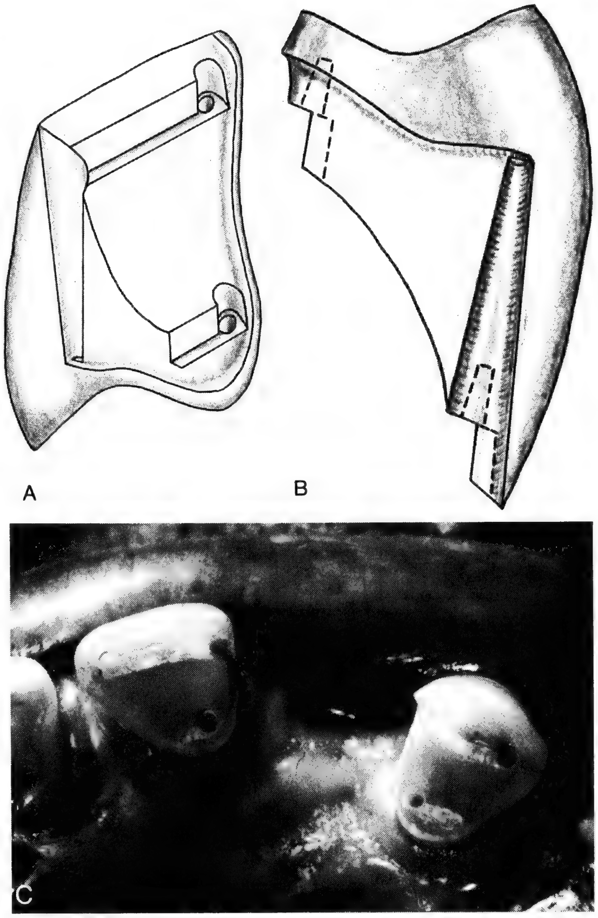


FIGURE 7–11

A, Proximal groove modification.
B, Proximal view.
C, Central incisor and canine prepared with proximal grooves adjacent to edentulous area.

An additional short linguoproximal groove can also be used on the nonedentulous side to increase the retention and resistance form (Fig. 7–12).

FIGURE 7–12 Canine preparation with distal proximal groove and short mesiolingual proximal groove.

Noninvolvement of the Incisal Edge

Mandibular anterior teeth are not ideal candidates for the conventional pinledge retainer, since the incisal bevel normally used would display considerable metal. However, when there is sufficient lingual and proximal crown length for retention, it is sometimes possible to avoid extending the preparation over the incisal edge. When the incisal edge is not involved, there is no display of metal, and the ideal esthetic result is attainable. This type of preparation is useful mainly on mandibular teeth because the occlusion normally occurring on maxillary anterior teeth would tend to dislodge the tooth from the retainer. Also, the normal contacts on maxillary teeth in eccentric positions of the mandible would often involve burnishing and distortion of the incisal margins, which would cause failure of the restoration.

On maxillary canines, it is possible to avoid preparation of the mesial cusp arm when there is no centric or eccentric occlusal contact occurring on this area. This design variation eliminates metal over the highly visible mesial cusp arm and greatly enhances the esthetic result (Fig. 7–10).

8

Temporary Restorations

Prepared abutment teeth must be restored temporarily while the final prosthesis is being fabricated in order to provide protection, positional stability, mastication, and esthetics and to obtain certain diagnostic information.

FUNCTIONS OF TEMPORARY RESTORATIONS

PROTECTION

Prepared teeth must be covered in order to protect the pulp from thermal and chemical irritation caused by foods and liquids, dental plaque accumulation, and the passage of air during breathing.

Periodontal health is also supported by a temporary prosthesis that enhances rather than hinders effective oral hygiene procedures. To accomplish this goal, the restoration must fit the margins of the preparation, have normal axial contours, and possess cervical embrasure form that allows access to the gingival tissues for oral hygiene procedures. In addition, the restoration must be made of a dense material that is smooth and well polished.

A temporary restoration protects the integrity of the prepared tooth. Fracture or abrasion can result if the opposing dentition contacts the completed preparation in eccentric mandibular positions or if hard foods are chewed on an unprotected margin. This problem is critical with partial-coverage preparations, and damage can require remaking of the restoration or even redesign of the preparation.

Also, the cheeks, tongue, and lips can be protected from inadvertent trauma during chewing by a properly designed temporary restoration.

POSITIONAL STABILITY

Temporary restorations must maintain the prepared teeth in the same mesiodistal, faciolingual, and occlusocervical positions that they occupied when the working cast impression was obtained. This requires the restoration of normal proximal and occlusal contacts, since the absence of contact or the presence of heavy contact often causes tooth movement. Failure to maintain contacts may result in a final restoration that does not seat properly on the prepared teeth or that requires considerable occlusal adjustment. Opposing and adjacent teeth may also move from their positions as the result of a temporary restoration that lacks adequate contact with these teeth.

The position of the gingival tissues relative to the prepared teeth is maintained by properly fitting and contoured temporary restorations, whereas gingival recession can occur from an overcontoured or poorly fitting subgingival restoration. Also, a temporary restoration that is short of the preparation margin allows the gingiva to collapse over the margin. This situation often leads to excessive soft tissue trauma from gingival impingement and displacement as the final restoration is seated.

A temporary restoration can also help maintain the normal esthetic position of the lip or cheek when multiple anterior or posterior teeth are missing.

When a temporary fixed prosthesis is made, it is important that the pontic allow for normal or enlarged embrasures and that it not contact the ridge tissues with pressure. Impingement of the ridge tissues may lead to alteration of ridge form as a result of the formation of hyperplastic tissue caused by direct irritation and the patient's inability to effectively remove dental plaque.

MASTICATION

Temporary restorations usually allow for reasonable mastication of food while the final prosthesis is being fabricated. The amount of function achieved depends on the resistance to deformation exhibited by the material used for the temporary restoration, the retention of the preparation, the span length, and the occlusal forces exerted in the area.

The restoration must produce proper occlusal relationships with the opposing teeth, since the dental pulp can

be injured, or tooth mobility produced, by traumatic occlusion created by a poorly integrated temporary restoration.

Esthetics

In edentulous areas of the mouth that are visible during talking, smiling, or laughing, temporary restorations are necessary in order to provide the patient with a full complement of teeth that possess a shape and color compatible with the oral environment.

Diagnostic Information

Temporary restorations may be used to provide information relative to the best tooth form and arrangement for the final restorations. They also allow decisions relating to lip support and phonetics to be made before the final restoration is fabricated. The periodontal prognosis for abutment teeth, as well as the response of teeth to additional occlusal force, can be determined through the placement of temporary restorations. The oral hygiene habits of the patient can be observed, and the information that is gained can influence the design of a final prosthesis. The acceptability of a new mandibular position, a new occlusal interdigitation, and a new vertical dimension of occlusion can be evaluated.

MATERIALS FOR TEMPORARY RESTORATIONS

There are many different types of temporary crowns available for interim restoration of prepared teeth. They may be made from either metal or resin. Preformed temporary crowns can be made from a stock selection of aluminum shells, transparent resin crown forms, polycarbonate crowns, stainless steel crowns, and Ni-Chro or Iso-Form crowns. These crowns can be luted directly to prepared teeth after adjustment, or they may be relined with a plastic material prior to cementation. Temporary restorations can also be custom-made from resin. Custom-made restorations have an advantage over the preformed variety in that the original tooth morphology is more easily reproduced as well as the relationships with adjacent and opposing teeth.

Single temporary restorations and temporary fixed partial dentures may be formed in the mouth directly on the prepared teeth, or they may be fabricated indirectly on a cast of the prepared teeth. For single crowns or small prostheses, the direct method can produce good results, but for large restorations with multiple abutment teeth, indirect fabrication on a cast generally produces better contour and fit than can be achieved in the mouth.

The temporary polymeric resin materials that are used for the construction of customized temporary crowns include the poly (methylmethacrylates), epimine resins, and polyethyl (butyl) methacrylates. For long-term use, a heat-curing resin, rather than an autopolymerizing one, often produces a more durable and stain-resistant temporary restoration. On a theoretic basis, construction of temporary self-curing resin crowns directly over prepared tooth surfaces would be damaging to the dental pulp. Both heat that is generated during resin polymerization and chemical irritation caused by the resin are potential sources of pulp injury. However, clinical experience indicates that this practice appears to be biologically safe. The period during which the resin contacts the prepared tooth surface is brief; furthermore, the restoration is generally cemented with zinc oxide and eugenol cement, a material known to have a low irritational potential.

Regarding the effect of temporary resins on gingival tissue, the accumulation of plaque on any rough surface of the restoration has a greater potential for tissue damage than any possible chemical irritation by the resin.

For temporary cementation, zinc oxide with eugenol is the most popular cement. However, now there is a tendency to use noneugenol cements based on a liquid-containing ortho-methoxy phenol, ortho-methoxy benzoic acid, and ortho-ethoxy benzoic acid. One of the reasons for the use of the eugenol-free cement is that the presence of free or leached eugenol has a softening effect on the resin. Regarding pulp and gingival response to eugenol-containing cements versus noneugenol zinc oxide preparations, the noneugenol materials do not appear to have an added biologic advantage over zinc oxide and eugenol.

For long-term temporary cementation for which higher compressive and tensile strengths are desirable, the polycarboxylate or glass ionomer cements can be used.

FABRICATING TEMPORARY RESTORATIONS

Direct Custom Resin Restorations

The first step in forming direct custom restorations is to make a mold or matrix of the desired form of the restoration together with that of the adjacent teeth and soft tissues. For single restorations, this is accomplished either through an intraoral impression of the intact tooth or, if the tooth has been extensively damaged, an impression of the diagnostic cast with the tooth waxed to normal contour. For a temporary fixed partial denture, the impression must include the form of the replacement teeth along with that of the abutments and adjacent teeth. This impression is obtained from a diagnostic cast on which the pontics have been formed in wax or by using resin denture teeth (Fig. 8–1). Either an alginate or a rubber-based impression may be obtained and set aside for future use. For this purpose, a rubber impression can be stored almost indefinitely, but an alginate impression must be used at the same appointment and should be wrapped in a moist towel to prevent dehydration.

Any tags of impression material that will interfere with reseating of the impression over the teeth must be cut away with scissors or a scalpel (Fig. 8–2). A self-curing resin of the required shade is selected and mixed in a dappen dish to a consistency that does not rapidly flow back together when a spatula is drawn through the mix (Fig. 8–3). The resin is placed into the impression, which is reseated directly over the prepared tooth or teeth (Fig. 8–4). The progress of polymerization of the resin is checked by probing the excess material that

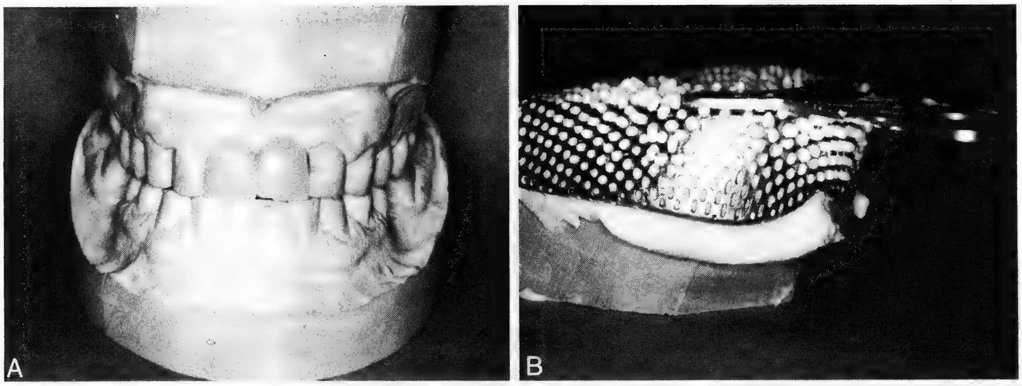


FIGURE 8–1

A, Central incisors formed in wax.
B, Alginate impression on cast.

flows beyond the impression. The polymerization of the excess resin in the dappen dish is not a reliable measure of the rate of polymerization in the mouth, since room temperature generally is lower than that of the oral cavity.

The impression is removed from the mouth, and the excess resin is removed from the undercuts before it hardens (Fig. 8–5). Otherwise, the excess resin will lock into the undercuts, and removal may have to be accomplished by sectioning, thus destroying the restoration. The restoration is removed and then reseated to verify that no significant distortion has occurred during removal of the excess. Following complete polymerization of the resin, the excess that flowed beyond the margins and that which remains interproximally is removed using a bur or paper disc (Fig. 8–6). These instruments are slowly rotated toward the margin to avoid overheating of the resin and softening and distortion. For fixed partial dentures, cervical embrasures must be formed to allow access to the soft tissue with oral hygiene aids.

FIGURE 8–2 Removal of interproximal impression material to facilitate accurate reseating of the impression in the mouth.

FIGURE 8–3 Resin properly mixed for direct temporary restoration.

The restoration is then clinically reseated for evaluation. It should fit the margins of the preparation, be a continuation of normal tooth contour, and reestablish proximal contact with the adjacent teeth. Centric occlusal contacts are marked and adjusted until simultaneous contact is achieved with the remainder of the dentition (Fig. 8–7). The temporary restoration is checked in eccentric mandibular movements to ensure that there are no interferences.

The correction of negative defects is accomplished by using the bead-brush technique to add resin while the restoration is seated on the tooth. This procedure uses one dappen dish with resin liquid (monomer), another with the powder (polymer), and a small brush. The brush is dipped into the monomer to moisten the bristles and then placed into the polymer. The bead of resin that forms around the tips of the bristles is carried to the tooth and allowed to flow into position and to harden before removal of the temporary restorations and final finishing.

Following adjustments, the restoration is polished with pumice using a rag wheel in a lathe and then by a resin polishing compound, also on a rag wheel. The high polish makes the restoration more cleansable and less susceptible to surface staining and facilitates the removal of excess temporary cement (Fig. 8–8).

For temporary fixed partial dentures for which there is no need for normal pontic form, a clinical impression containing only the abutment teeth can be made prior to tooth preparation. Upon removal of the impression from the mouth, a barlike portion of impression material is cut away from the edentulous ridge between the abutment teeth. When this area is filled with resin and reseated over the prepared teeth, a resin bar is formed

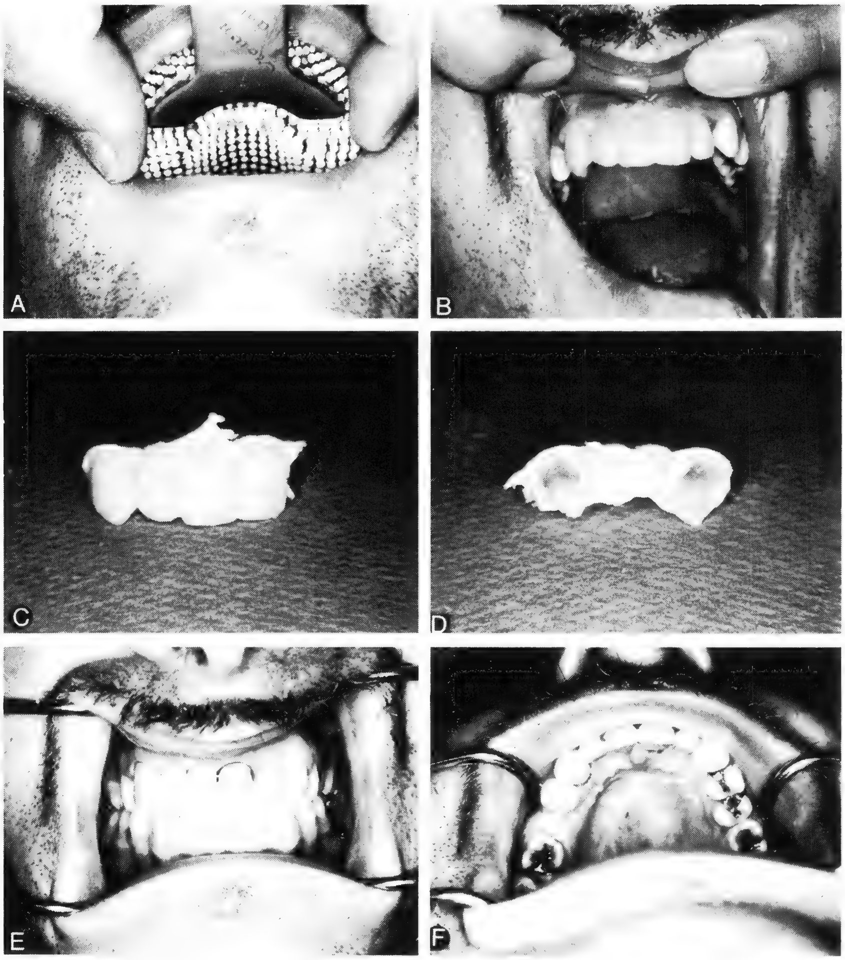


FIGURE 8–4 Direct Fabrication of Temporary Fixed Prosthesis

A, Filled impression seated in mouth.
B, Before removal for trimming.
C, D, Temporary restoration removed.
E, F, Temporary restoration trimmed, polished, and seated with temporary cement.

that connects the abutment restorations (Fig. 8–9). Cervical embrasures are formed, and the area of ridge contact is altered as the restoration is shaped.

An alternative to the use of impression material for obtaining the mold for the temporary restoration is the use of a vacuum-formed plastic coping. This process involves using a machine that heat-softens a thin plastic sheet and then adapts it under vacuum to a diagnostic cast that has the required tooth form. If the tooth has been damaged in any way, its form is reestablished on

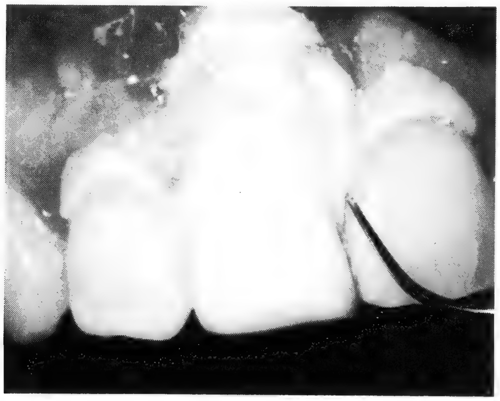


FIGURE 8–5 Explorer being used to free partially set excess resin from proximal undercut. Restoration is then removed and allowed to set before trimming and finishing.

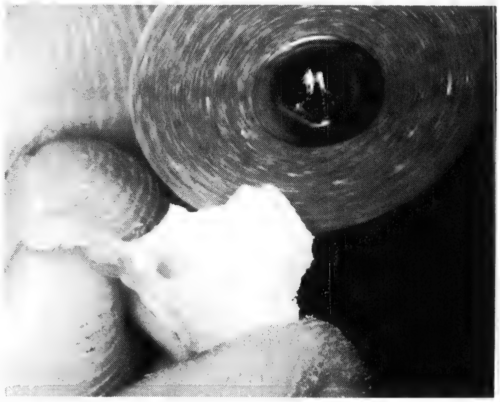


FIGURE 8–6 Excess resin removed with sandpaper disc. For best cutting, rotation of disc is from margin toward restoration.

FIGURE 8–7 Uniform occlusal contacting of natural teeth and temporary restoration.

FIGURE 8–9 Resin bar used to ensure maintaining axial relationship while a fixed prosthesis is fabricated.

the cast by using a material that will not be distorted when the hot plastic sheet contacts the tooth. Wax is not satisfactory for this purpose. Mortite, a puttylike material used for temporary weather stripping and available at hardware stores, can be used to recreate tooth forms on the cast. A similar putty is also available through the manufacturer of the vacuum machine. For temporary fixed partial dentures, the pontic form is established using denture teeth, since the heat and pressure of the vacuum process distorts wax or a large bulk of the putty material (Fig. 8–10A).

The cast must be trimmed so that it has a flat base to allow total contact with the machine's perforated metal platform, through which the vacuum is applied. The periphery of the cast should also be trimmed so there are no large voids, undercuts, or sharp areas remaining that may produce perforation of the softened plastic sheet and result in a loss of vacuum as the sheet is being drawn down over the cast. The cast must also be dry, since moisture interferes with good vacuum adaptation.

The cast is centered on the perforated platform, a piece of 0.020-inch coping material clamped into the vacuum machine, and the heating element is placed over the plastic sheet and turned on. The plastic softens from the heat and sags toward the cast. The vacuum pump is then turned on, and the plastic sheet is lowered until it covers the perforated metal platform on which the cast is located. The heating element is switched off and moved aside so that it is not over the plastic sheet. The vacuum pump is kept running for 10 to 15 seconds until the plastic hardens.

A scalpel is used to cut out a portion of the adapted plastic sheet. This must include the teeth being restored, the surrounding soft tissue, and also some adjacent teeth in order to permit proper orientation in the mouth after the teeth are prepared (Fig. 8–10B). Mixed temporary resin is allowed to flow into the plastic form (Fig. 8–10C), which is then fully seated over the prepared teeth and held in place until the resin begins to harden (Fig. 8–10D). The restoration is removed before it hardens completely. It is then trimmed and reseated, and form corrections are completed. The restoration is adjusted and polished in the manner previously described.

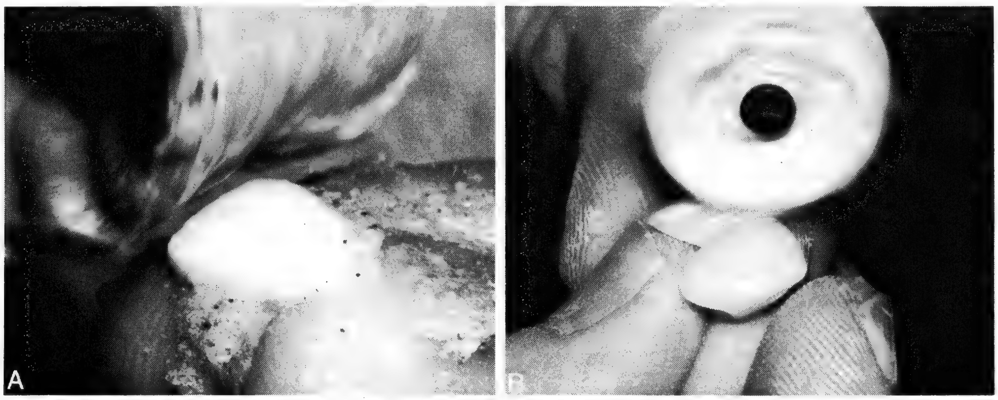


FIGURE 8–8

A, Temporary restoration being polished with pumice and rag wheel. Margins are protected by operator's thumb.

B, High polish is produced with resin polishing agent and clean rag wheel. Again, the thumb protects the margins.

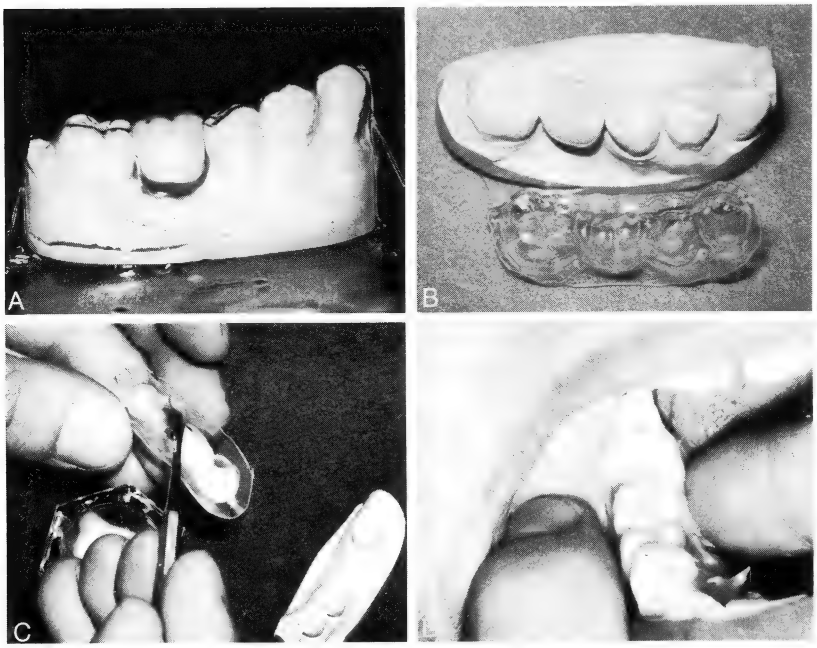


FIGURE 8–10 Use of Vacuum-Formed Matrix in Fabricating a Temporary Prosthesis

A, Matrix adapted to cast with denture tooth used to form pontic.
B, Matrix trimmed with scalpel and removed from cast.
C, Resin mix being placed in matrix.
D, Matrix in place on prepared teeth.

In the absence of a vacuum-forming machine, it is still possible to adequately adapt the plastic sheet material to a cast. This is done by holding the plastic in a metal frame over a Bunsen burner until it softens. It is then placed over the cast, and modeling clay is used to press the sheet into contact with the cast.

Indirect Custom Resin Restorations

The laboratory fabrication of temporary restorations is handled similarly to the direct procedures except that the resin is adapted to a cast of the prepared teeth.

The first step involves making a mold of the desired restoration form. This is accomplished as previously described by making a vacuum-formed matrix or an impression (Fig. 8–11A).

Following tooth reduction, a cast of the prepared teeth is obtained and placed into the impression to check for accurate seating (Fig. 8–11B,C). Any interproximal tags that would interfere with accurate placement of the cast are removed. Then, the prepared teeth and surrounding area of the cast are coated with a resin separating medium and allowed to dry (Fig. 8–11D). Properly mixed resin is placed into the impression, and the cast is fully seated (Fig. 8–12A,B). The resin is allowed to harden and the cast is destroyed to ensure intact retrieval of the temporary restoration (Fig. 8–12C). The restoration is evaluated clinically and adjusted (Fig. 8–12D). A temporary fixed partial denture involving multiple pontics or partial-coverage retainers is best accomplished by an indirect procedure (Fig. 8–13).

Polycarbonate Temporary Crown

A single temporary restoration can be fabricated using a thin-walled tooth-colored polycarbonate crown, which is manufactured in an assortment of sizes and molds. The crown is adapted internally by filling it with an autopolymerizing resin and seating it over the prepared tooth. These crowns are manufactured in a medium color and are without the wider range of shades available with custom resin temporary restorations. However, the polycarbonate material is more resistant to discoloration than are custom resin crowns. While a fairly wide range of anterior polycarbonate crown shapes is available, the variety of posterior crowns is limited.

The technique begins by measuring the mesiodistal width needed in the temporary restoration and selecting the appropriate crown from the available sizes (Fig. 8–14A). If the measurement falls between two sizes, the larger crown is selected and material is reduced from the proximal surfaces. Use of the smaller crown would result in a lack of proximal contact.

The cervical form is achieved with an acrylic cutter until it follows the contour of the finish line and the desired incisocervical dimension is obtained (Fig. 8–14B). The crown may be left slightly long incisally so that subsequently it can be shaped to the desired form.

Autopolymerizing resin is mixed to a flowable consistency and placed inside the polycarbonate crown, and the crown is seated over the prepared tooth to create an intimate adaptation to the axial walls and finish line (Fig. 8–14C). Excess material is expressed cervically. Before the crown completely hardens, it is removed so that surplus resin that has flowed into interproximal undercuts can be eliminated. The restoration is then reseated and examined for any distortion that may have occurred during trimming.

After the resin has hardened, any remaining cervical excess is removed. Both the polycarbonate material and resin are reduced simultaneously to achieve the desired cervical form. The restoration is replaced on the tooth for finalization of the form and occlusal adjustment (Fig. 8–15). Correction of deficient areas is accomplished as previously described, and the restoration is polished.

Polycarbonate crowns may also be adapted indirectly to a stone cast instead of directly on the prepared tooth.

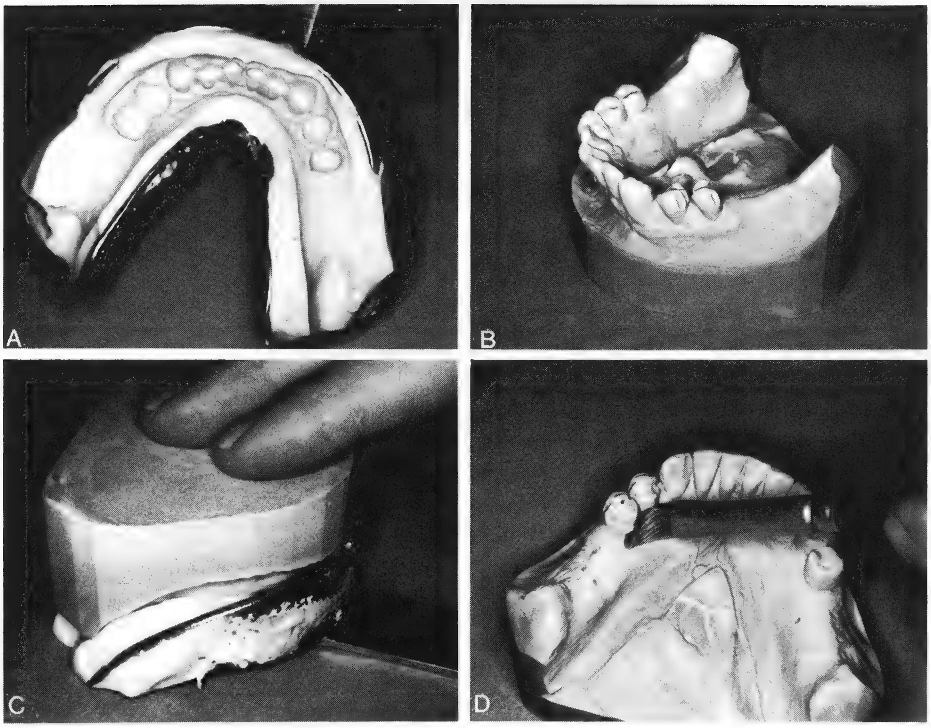


FIGURE 8–11 Indirect Fabrication of Temporary Restoration

A, Alginate impression to be used as mold for temporary restorations.
B, Working cast from alginate impression taken after tooth preparation.
C, Working cast checked for seating in impression.
D, Prepared teeth and adjacent area coated with resin separating medium.

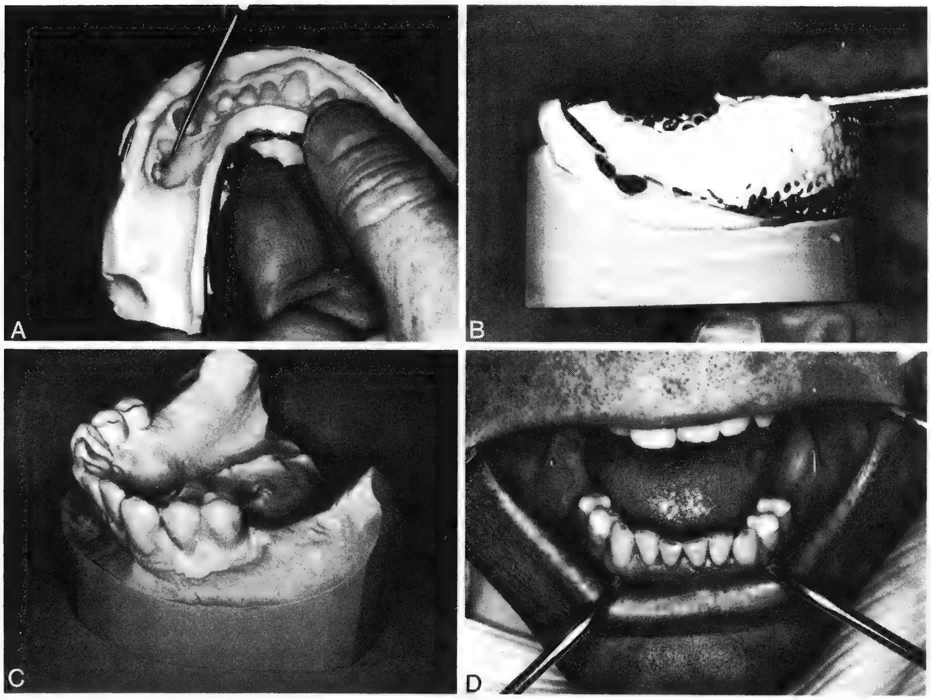


FIGURE 8–12 Indirect Fabrication (Continued)

A, Resin placed in impression.
B, Cast seated in impression.
C, Completely set resin restorations on cast.
D, Restorations temporarily cemented on prepared teeth.

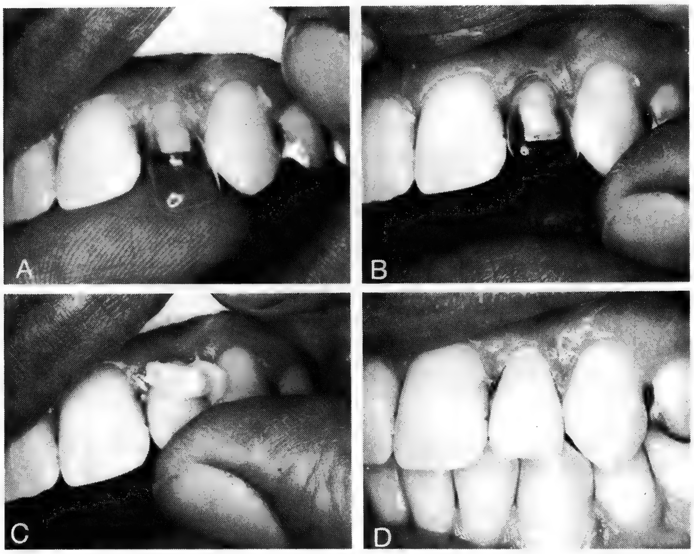


FIGURE 8–16 Clear Plastic Crown Form
A, B, Fitting plastic crown form.
C, Crown form filled with resin and seated.
D, Luted temporary crown. Crown form remains in this instance.

Clear Plastic Crown Forms

Thin transparent plastic crown forms are available for single restorations. They are selected and adjusted to the prepared tooth in a manner similar to that used for the polycarbonate crown form. The clear form is filled with autopolymerizing resin, seated over the prepared tooth, and the excess material removed as previously discussed (Fig. 8–16).

The plastic crown form does not bond to the resin. Thus, it usually must be removed from the set temporary restoration by slicing through the thin material. This results in the loss of proximal contacts, which requires additional material to be added to these areas. Failure to remove the plastic form may create problems during shaping of the marginal area and axial surfaces, since the lack of bonding precludes a smooth transition between the two materials. Also, if left in place, the plastic form may peel away during function, causing the loss of proximal and occlusal contacts.

Aluminum Shell

Preformed aluminum shells are available in several sizes for temporary restoration of individual molar and premolar teeth. Those with an anatomic occlusal surface are easier to adapt and have a more acceptable final shape than those with a canlike form. The main advantage of the aluminum shell crown is that its adaptation to the tooth does not require advance preparation in the form of casts, impressions, or vacuum-formed matrices.

A shell is selected with the proper mesiodistal dimension. If the exact size is not available, a slightly smaller or larger one can be adjusted with contouring pliers. The cervical extension of the shell is cut with curved scissors to follow the finish line and to adjust the occlusocervical height. This requires cutting and reseating of the shell several times to finalize the adaptation. The axial surfaces are then adjusted with contouring pliers to follow the cervical tooth contour, and the occlusion is adjusted by shaping the metal with a ball burnisher in areas that interfere with normal occlusion. Eliminating occlusal interferences by having the patient forcibly occlude should not be done, since this may cause the metal margin to impinge on the tooth and possibly cause damage to the finish line or injury to the gingiva or periodontal ligament. After all adjustments have been completed, the margin of the shell is smoothed with a fine paper disc or rubber wheel.

Relined Aluminum Shell

The preceding method often produces relatively poor marginal adaptation, cervical contour, and occlusal interdigitation. Some of these limitations can be overcome by relining the aluminum shell with an autopolymerizing resin. This allows contouring of the marginal, cervical, and occlusal areas to a more acceptable form, since perforation of the thin metal during shaping exposes only resin. This type of crown resists heavy occlusal forces better than the all-resin restoration, since the metal aids the resin in resisting deformation and subsequent dislodgment.

The aluminum shell is adapted to the tooth by cutting and contouring the metal as previously described. The internal surface is roughened with a bur to promote mechanical interlocking of the acrylic resin with the metal. The shell is then filled with resin, seated over the prepared tooth, and the excess material removed. Following complete polymerization of the resin, the contour of the restoration is finalized (Fig. 8–17).

As the occlusion is adjusted, the metal shell often is perforated and the underlying resin becomes exposed. The restoration is polished in the standard manner.

Cast Temporary Restorations

When a temporary restoration is needed for an extended period of time, a casting is often the most serviceable type and is readily cleansed. This type of restoration is needed when orthodontic realignment of teeth

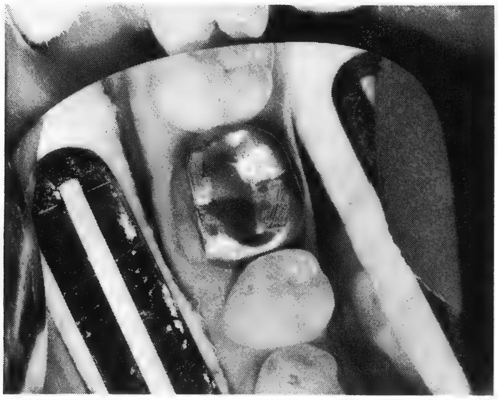


FIGURE 8–17 Aluminum shell crown that has been trimmed and then relined with temporary resin to form a temporary partial veneer crown.

is required prior to fabrication of the final restoration or during extensive rehabilitation. Also, a cast restoration may be needed to promote healing during periodontal therapy.

Temporary Repair of Existing Restoration

When an existing casting is being replaced, it can often be used as a temporary restoration following its removal. A common method of removing existing extracoronal castings is to cut a slot through the metal and expand the casting using an instrument to create bending forces in the slot (crown removal is discussed in Chapter 29). The slot can be filled with resin and the casting relined if necessary. The resin material must be mechanically locked into the crown by creating undercuts in the metal (Fig. 8–18).

Combination Indirect-Direct Fabrication

Temporary fixed partial dentures can be made by directly relining a prosthesis made in the laboratory on an altered diagnostic cast prior to clinical tooth preparation.

For this procedure, abutment defects are corrected on the cast with wax, and pontic form is established using wax, plastic denture teeth, or preformed crowns. Proximal joint form is created in wax, and an impression is made to produce the mold for making the temporary prosthesis.

Once the mold is made, the wax and other materials used to establish form are removed from the cast. The stone teeth are reduced minimally to simulate the final abutment preparations, and a coating of resin separator is applied (Fig. 8–19A).

The impression is filled with resin in the area of the prosthesis and seated over the cast (Fig. 8–19B,C). When the resin polymerizes, a temporary fixed partial denture is obtained with thin-walled abutment retainers (Fig. 8–19D).

Since the amount of clinical tooth reduction will be greater than the conservative reduction performed on the cast, an internal space is created between the temporary restoration and the prepared tooth (Fig. 8–20A). The internal adaptation of the prosthesis is achieved by placing additional resin into the retainers and seating the restoration directly over the prepared teeth (Fig. 8–20B, C, D). It is then adjusted and polished as usual.

Temporary Restorations for Pinledge Preparations

Fabrication of these restorations is best accomplished by formation directly on the prepared tooth. Plastic pins are seated into the pinholes of the preparation and resin is made to flow around the pins and over the prepared surfaces in increments, using the bead-brush technique, until the desired form and thickness are achieved (Fig. 8–21). After the resin hardens completely, a sharp spoon excavator is used to lift the plastic away from the margin and to pull the restoration free from the tooth for adjustments and polishing (Fig. 8–22).

With a fixed partial denture that utilizes a pinledge retainer, a single temporary restoration is formed on the pinledge preparation and then intraorally connected to the remainder of the bridge.

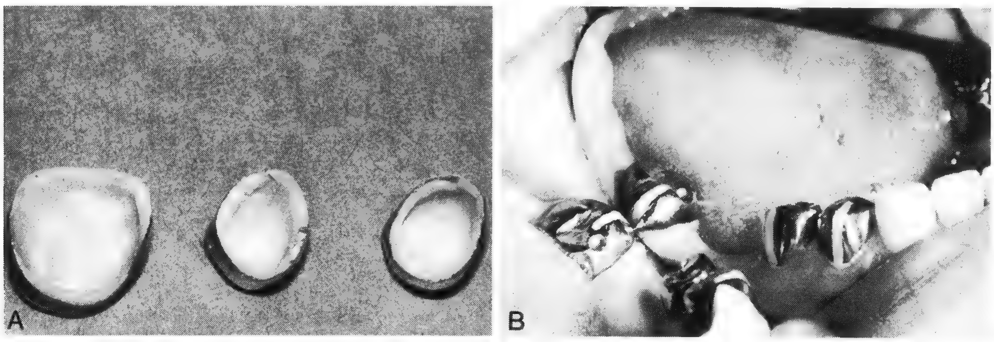


FIGURE 8–18 Temporary Readaptation of Cast Restoration

A, Old full veneer crowns readapted to reprepared teeth with temporary resin.
B, Restorations temporarily cemented.

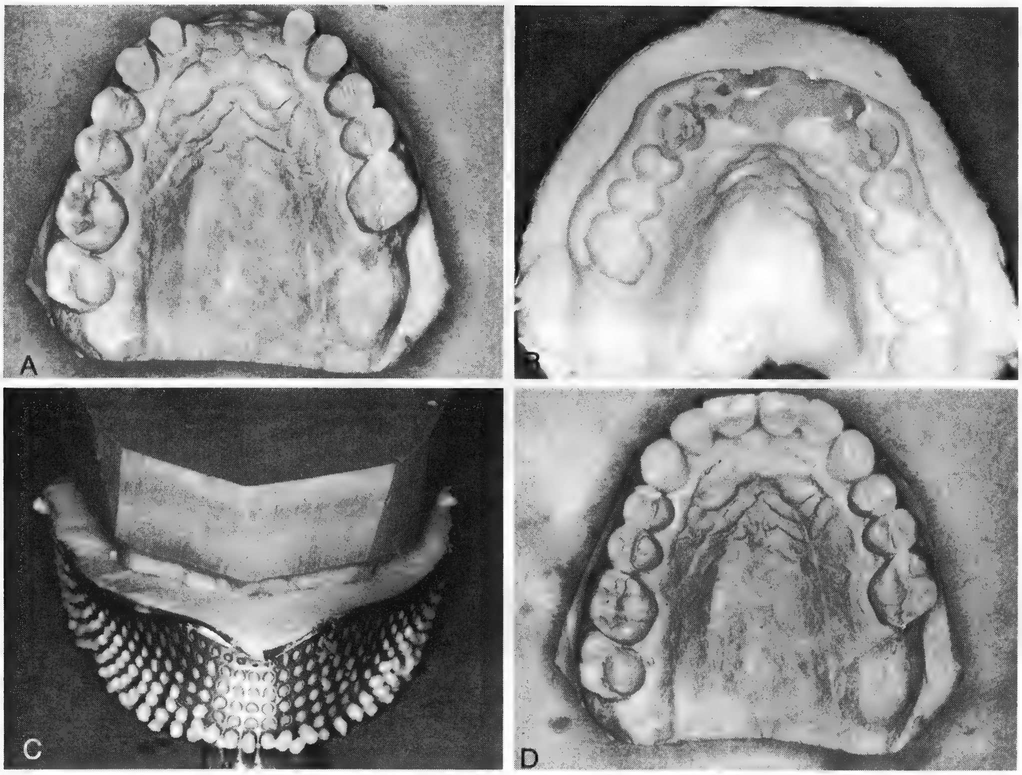


FIGURE 8–19 Indirect-Direct Fabrication of Temporary Fixed Prosthesis

A, Shallow preparations made on diagnostic cast.
B, Resin placed in previously made alginate impression.
C, Cast with prepared teeth seated in impression.
D, Completely hardened resin on cast.

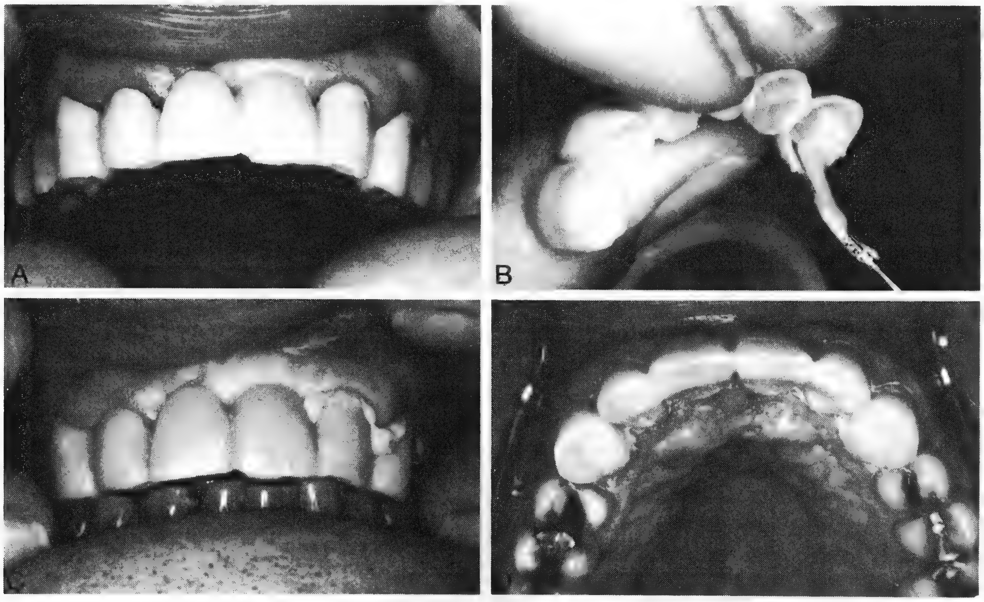


FIGURE 8–20 Indirect-Direct Fabrication (Continued)

A, Temporary prosthesis placed over completed tooth preparations for evaluation.
B, Placing mixed resin in retainers.
C, Prosthesis seated with excess resin at margins.
D, Finished prosthesis cemented.

FIGURE 8–21 Temporary Restoration of Pinledge Preparation

A, Plastic pins suitable for use with temporary restoration.
B, Pins in place in preparation pinholes.
C, Application of resin around plastic pin using bead-brush method.
D, Further buildup of resin to achieve oversized form.

Intraoral Assembly of Individual Units

A temporary fixed partial denture can be made intraorally by connecting a pontic to individual temporary restorations. The pontic may be a plastic denture tooth, a polycarbonate crown filled with resin, or one custom-fabricated from temporary resin. It is attached to the retainers by the bead-brush technique to form resin connectors (Fig. 8–23).

Another indication for this procedure is when there has been distortion of a temporary bridge that was fabricated in one piece. The error can sometimes be corrected by sectioning the restoration, reseating the individual parts, and if they now fit properly, reconnecting them with resin using the bead-brush technique.

Temporary Restorations for Endodontically Treated Teeth

After tooth preparation, some endodontically treated teeth may have sufficient coronal tooth structure remaining so that they can be restored temporarily by one of the previously described techniques. However, many endodontically treated teeth have little coronal tooth structure remaining after preparation, so that retention of a temporary restoration is difficult while the post and core is being fabricated. In such cases it is often necessary to gain additional retention by using the space prepared in the root canal.

For an anterior tooth, a polycarbonate or clear plastic crown is trimmed to fit the cervical crown form and finish line. A piece of sufficiently stiff orthodontic wire, or a plastic post, is cut to a length that extends from the depth of the root canal preparation to a point inside the crown form that does not interfere with proper seating (Fig. 8–24A, B). The wire requires notching with a bur to provide mechanical retention for the resin. The fitted post is then placed into the root canal space. Mixed resin is made to flow inside the crown form, which is fully seated over the tooth to cause the resin to be forced around the wire or plastic post and partially down the root canal (Fig. 8–24C). It is mandatory that the restoration be removed and replaced several times before the

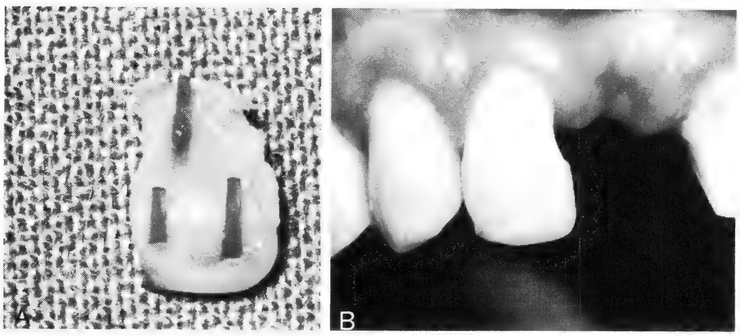


FIGURE 8–22 Temporary Pinledge (Continued)

A, Hardened resin pinledge removed from tooth.
B, Pinledge trimmed and replaced on tooth.

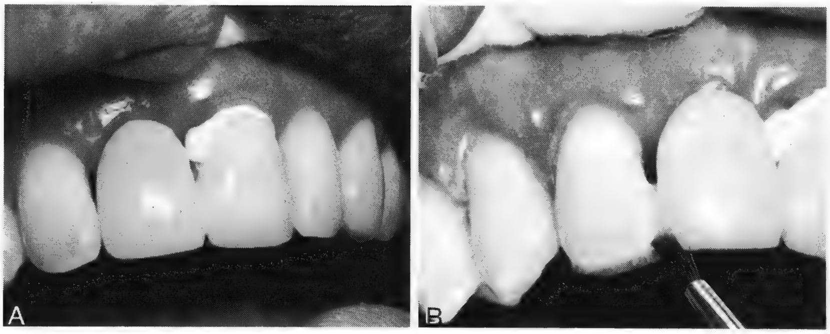


FIGURE 8–23 Intraoral Assembly

A, The central incisor crown with attached pontic has been luted to the prepared abutment tooth.
B, Attachment of the cemented lateral incisor temporary pinledge to the central pontic is accomplished by means of a carefully applied bead-brush technique.

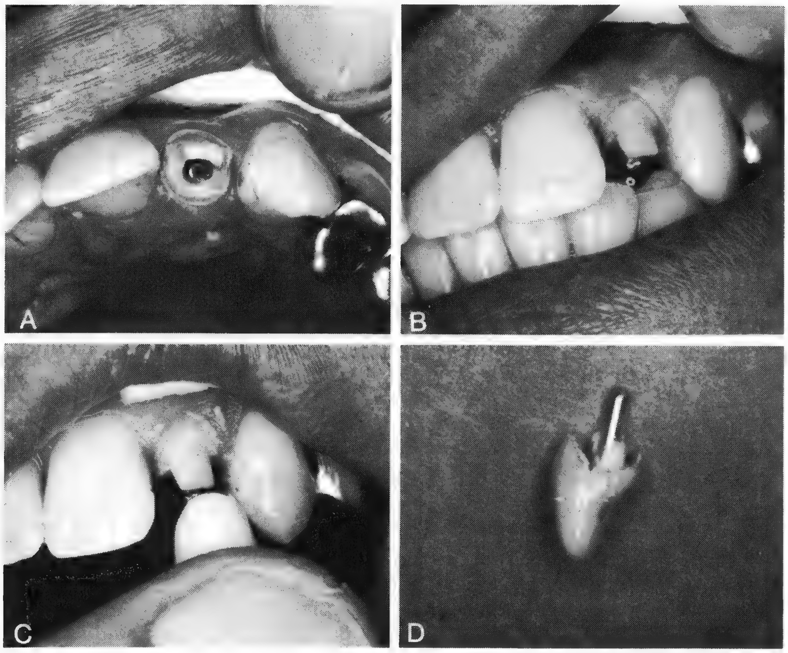


FIGURE 8–24 Temporary Restoration of the Endodontically Treated Tooth

A, B, Fitting plastic crown form to endodontically treated tooth. Post wire has been adapted to enlarged canal.
C, Crown filled with temporary resin.
D, Temporary crown removed.

FIGURE 8–25

A, Endodontically treated maxillary molar with little coronal tooth structure remaining.
B, Aluminum shell crown adapted to the tooth with temporary resin and incorporating a preformed plastic post for retention.
C, Restoration placed on tooth.

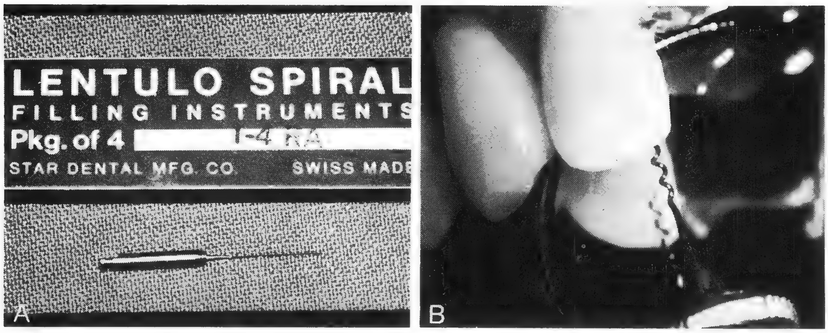


FIGURE 8–26

A, Spiral dental handpiece instrument used for carrying cement with pinholes.
B, Lentulo Spiral in pinhole.

resin completely hardens in order to prevent mechanical interlocking of the resin into any small undercuts present in the root canal (Fig. 8–24D).

For endodontically treated posterior teeth, polycarbonate or aluminum shell crowns may also be fabricated using a wire or plastic reinforcing post when there is little or no remaining coronal tooth structure (Fig. 8–25).

When a cast post and core is being fabricated and the missing coronal tooth structure does not present an esthetic problem, temporary protection of the tooth may be accomplished by using cotton pellets in the depth of the root canal with cement placed over the top to prevent food from packing into the canal.

CEMENTATION OF TEMPORARY RESTORATIONS

The prepared tooth is isolated using cotton rolls to prevent the cheek and tongue from contacting the tooth and to absorb saliva. Compressed air is used to dry the tooth, and the restoration is cemented using a zinc oxide-eugenol or similar temporary cement.

Only a thin layer of cement is placed inside a well-adapted restoration, whereas a larger amount is required with the unlined aluminum shell because of its poor internal adaptation.

Cementation of a pinledge temporary restoration is accomplished by flowing a thin film of cement over the restoration and then placing cement into the pinholes of the prepared tooth with a slowly rotating Lentulo Spiral instrument. When this corkscrewlike instrument rotates, the cement flows down the pinhole, following the spiral form of the instrument (Fig. 8–26).

Prior to cementing a temporary restoration for an endodontically treated tooth, cotton pellets should be placed in any apical portion of the post space that will not be occupied by the restoration. This measure eliminates the difficult removal of cement from deep portions of the post space.

All excess hardened cement must be removed and the gingival sulcus carefully inspected for any cement remnants by using the tip of an explorer. Dental floss is used interproximally. Having a smooth highly polished surface on the restoration greatly facilitates removal of the excess cement.

HOME CARE INSTRUCTIONS FOR TEMPORARY RESTORATIONS

Instructions regarding brushing, flossing, and the use of other oral hygiene aids should be reinforced so that gingival health can be maintained while the final prosthesis is being fabricated. Functional activity on temporary restorations should be limited to the chewing of the softer nontenacious foods.

9

Articulators and Mounting Procedures

Fabricating restorations that occlude and function properly requires relating the working and opposing casts so that the same occlusal relationships are present that exist intraorally. This process is accomplished by clinically recording tooth interrelationships and using this information to position the casts in a dental articulator.

TYPES OF ARTICULATORS

An *articulator* is a mechanical instrument capable of maintaining opposing casts in their correct interocclusal relationship while allowing certain mandibular movements to be simulated or duplicated. The number of achievable mandibular movements and the accuracy of reproduction are often used to classify the different types of articulators.

NONADJUSTABLE ARTICULATORS

There are two types of instruments that cannot be adjusted: the simple hinge and the hinge with fixed condylar guidance controls. The simple hinge, which is also known as the plain-line or straight-line articulator, possesses only the ability to produce opening and closing mandibular movements (Fig. 9–1). Centric occlusion can be accurately recorded and maintained, but no information is available regarding eccentric mandibular movements (protrusive, working, nonworking, or lateroprotrusive). Articulators with fixed condylar controls permit some eccentric movements to occur, but they are limited in direction and form and cannot be altered to accommodate individual patient variations (Fig. 9–2). Also, these articulators are usually small, with the condyles being closer together than in the skull, so that the casts can produce movements that do not follow actual intraoral pathways.

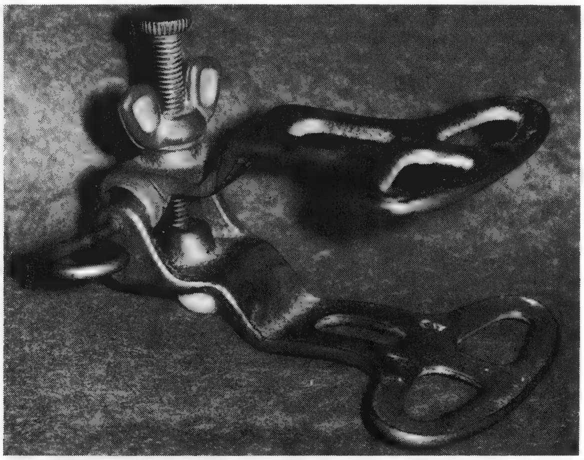


FIGURE 9–1 Simple hinge articulator.

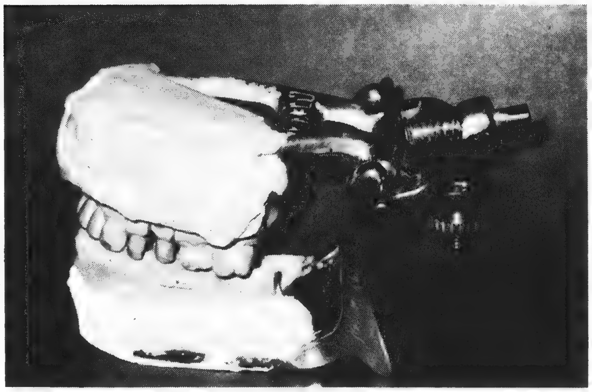


FIGURE 9–2 Hinge articulator with fixed condylar guidance.

SEMIADJUSTABLE ARTICULATORS

These articulators are anatomically more nearly normal in size and design and can be adjusted to individually different mandibular movements. Both of these features allow casts to follow pathways that more closely approximate those found in the mouth. However, they do not exactly reproduce all mandibular movements, since the clinical information used to set these instru-

ments is recorded only at the starting and ending points of a particular movement with the character of the movement between these points being only an average. They are therefore known as semiadjustable articulators. Nevertheless, the amount and accuracy of clinical information is greatly magnified when compared with the use of a nonadjustable instrument, and less intraoral adjustment of the prosthesis is generally required in eccentric mandibular movements.

There are two designs of semiadjustable articulators: arcon and nonarcon. The word "arcon," derived by combining portions of the words "articulator" and "condyle," identifies those instruments that are anatomically normal in design in that the condyles are attached to the lower member of the articulator and that the guiding elements, corresponding to the glenoid fossae, are attached to the upper member* (Fig. 9–3). Nonarcon instruments are manufactured with the condyles attached to the upper member and the guiding surfaces attached to the lower member† (Fig. 9–4).

Nonarcon articulators are only available with straight condylar guidance pathways, whereas arcon instruments are available with either straight (Fig. 9–3) or curved‡§ condylar guidance pathways (Figs. 9–5 and 9–6). Instruments with straight pathways allow the condyle to move only in a straight line during eccentric mandibular movements. Bennett movement or sideshift can be produced but only in a straight-line progressive form. There is no provision for immediate sideshift. Some of these instruments allow adjustment of the intercondylar distance, whereas others do not. All semiadjustable instruments provide for varying the angle of the eminentia (the angle formed between the axis-orbital plane and the superior wall of the glenoid fossa).

Since the skull rarely possesses flat condylar guiding surfaces, articulators with curved pathways are anatomically more nearly normal and allow relatively more accurate eccentric movements to be demonstrated. The curved condylar guiding surfaces represent the average form determined from precise clinical recording of mandibular movement. The superior guiding surface, which represents the curvature of the superior wall of the glenoid fossa, has a fixed curvature equivalent to a circle with a 0.75-inch radius. The medial guiding surface, which represents the medial wall of the glenoid fossa, forms a fixed angle of 7 degrees relative to the midsagittal plane of the skull.

*Whip-Mix Model 8500 Articulator, Whip-Mix Corp., Louisville, KY 40217.

†Hanau Model 96H2, Teledyne-Hanau, Buffalo, NY 14225.

‡Whip-Mix Model 8300 Articulator, Whip-Mix Corp., Louisville, KY 40217.

§Panadent Model "S" Articulator, Panadent Corp., Grand Terrace, CA 92324.

FIGURE 9–4 Hanau articulator Model 96H2. (Courtesy of Teledyne-Hanau.)

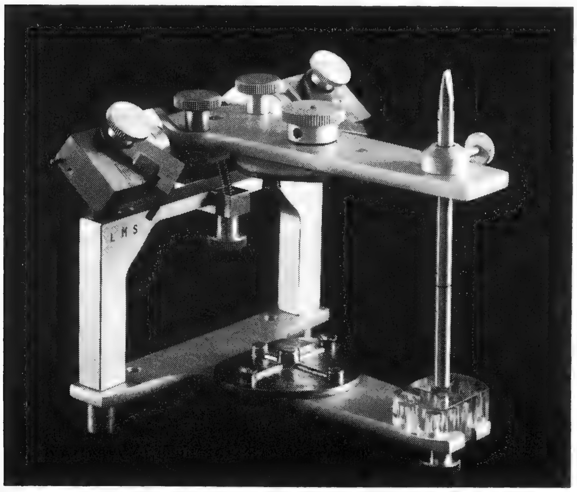


FIGURE 9–3 Whip-Mix articulator Model 8500. (Courtesy of Whip-Mix Corp.)

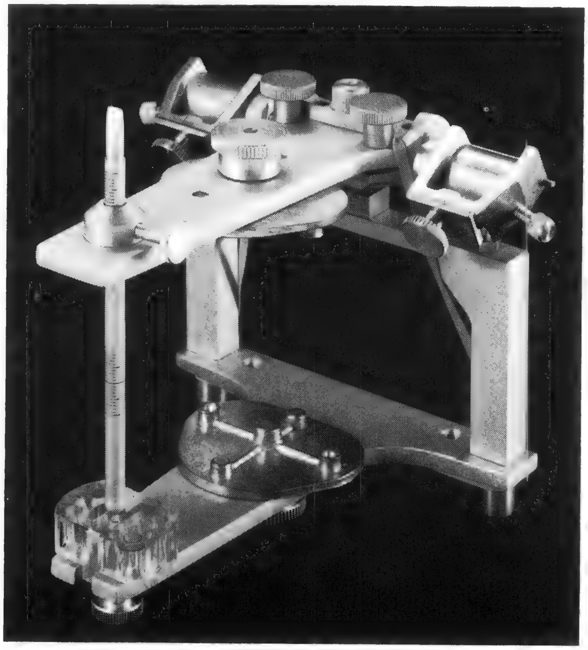


FIGURE 9–5 Whip-Mix articulator Model 8300. (Courtesy of Whip-Mix Corp.)

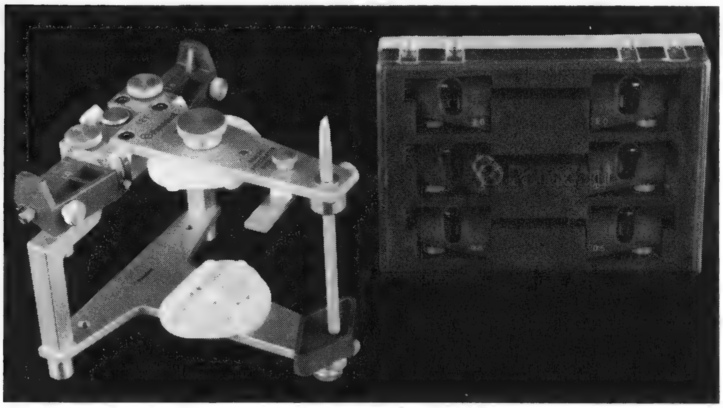


FIGURE 9–6 Panadent model "S" articulator. (Courtesy of Panadent Corp.)

These instruments permit adjustment of the angle of the eminentia and the amount of immediate sideshift. They typically possess an average intercondylar distance that is not adjustable.

Fully Adjustable Articulators

These instruments provide for the greatest amount of accuracy in reproducing mandibular movements, since both the direction and form of movement are accurately reproduced from the point of initiation to the point of termination. Adjustability includes the angle and curvature of the eminentia, the intercondylar distance, and the immediate and progressive sideshift.

The Stuart* (Fig. 9–7) and Denar† (Fig. 9–8) articulators are examples of fully adjustable articulators.

*Stuart Gnathological Computer, C. E. Stuart Gnathological Instruments, Ventura, CA 93001.

†Denar D5A Articulator, Denar Corp., Anaheim, CA 92805.

Articulator Selection

Fully adjustable articulators provide the ultimate in precision, which may be mandatory for the success of cases involving complicated occlusal disharmonies, temporomandibular joint disturbances, myofacial pain dysfunction, or other indications for complete oral reconstruction. However, such perfection in routine prosthodontic cases has not been proved necessary, and the procedures used to attain the required level of precision are both difficult and time-consuming, which significantly increases treatment cost.

The authors believe that most patients can be treated using semiadjustable articulators. These instruments can be adjusted by the use of intraoral interocclusal records so that they adequately simulate mandibular relationships.

Nonadjustable articulators are the most commonly used instruments in commercial dental laboratories. While it is true that many successful restorations have been fabricated using this type of instrument, a thorough knowledge of its limitations is mandatory if restorations are to be clinically adjusted to function harmoniously in eccentric mandibular movements. These

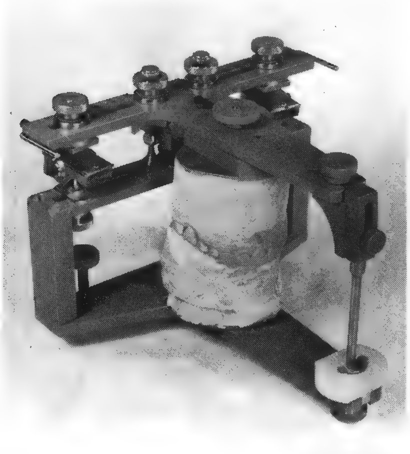


FIGURE 9–7 Stuart Gnathological Computer.

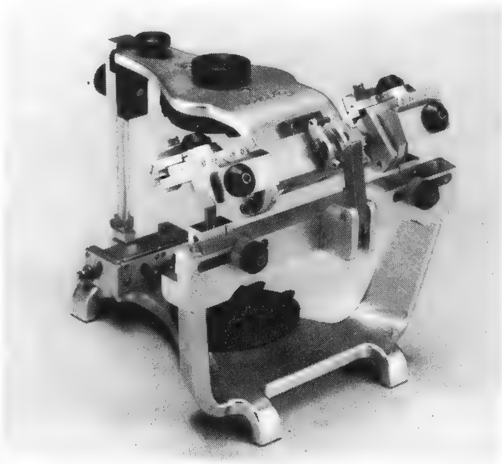


FIGURE 9–8 Denar D5A articulator. (Courtesy of Denar Corp.)

instruments are best used for single restorations and small prostheses that are not involved in controlling anterior tooth guidance.

MOUNTING CASTS IN A SEMIADJUSTABLE ARTICULATOR

Casts are rigidly affixed to the articulator by a gypsum material, either plaster or stone. They should occlude accurately when attached and be oriented so that the articulator can properly simulate or duplicate mandibular movements.

One mounting technique involves attaching the casts together and then orienting them by hand between the upper and lower members of the articulator. However, more accurate mandibular movements are produced when the casts are related to the articulator in the same manner as the teeth relate to the rotational centers of the jaw. This accurate relationship is accomplished by using a facebow, which is a bow-shaped device (Fig. 9–9) that can be assembled so it simultaneously contacts the maxillary teeth and three extraoral points of reference (the rotational center of each condyle and an anteriorly located reference point). When all the parts are tightened, the relationship of the maxillary teeth to the rotational jaw centers is recorded. The facebow is removed from the head and attached to the articulator, on which it relates the maxillary cast to the upper member in a predetermined three-dimensional relationship to the axes of the articulator. The mandibular cast is then related to the maxillary cast and attached to the lower member of the articulator.

TYPES OF FACEBOWS

Two types of facebows are available: the hinge-axis facebow and the average-axis facebow. The hinge-axis facebow relates posteriorly to the true axis of rotation, which has previously been located and marked on each side of the head. The hinge-axis facebow is used both to locate the axis and to relate the maxillary cast to the articulating instrument (Fig. 9–10).

The average-axis facebow is oriented so the posterior reference points are aligned with the average location

FIGURE 9–9 Whip-Mix No. 9600 Quick Mount facebow. (Courtesy of Whip-Mix Corp.)

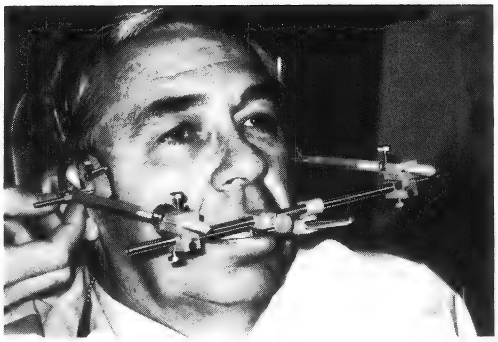


FIGURE 9–10 Stuart hinge-axis facebow being used to locate axis.

of the axis. These points are located by external facial measurements with some brands of facebows, whereas other brands fit into the ear openings and relate the axis relative to this position (Fig. 9–11).

WHIP-MIX AVERAGE-AXIS FACEBOW RECORDING

The Whip-Mix Quick Mount facebow makes use of an average axis. It is fixed to the patient's skull by means of plastic projections, which are inserted into each external auditory meatus.

The third point of reference used with this facebow is the concavity at the root of the nose, which corresponds approximately to the anthropometric landmark, the nasion. The facebow is adjusted to this point through an attachment carrying a half-round plastic part that must fit snugly into the concavity.

Preparation of Transfer Fork

The first step in obtaining any facebow recording is preparation of the transfer fork (sometimes called a bite fork). Wax is considered a suitable material with which to coat the transfer fork so that indentations of the teeth can be recorded. However, low-fusing compound also can be used and does not distort as easily as wax. A layer of wax or compound is placed on both surfaces of the fork (Fig. 9–12A) and while still slightly soft is forced against the maxillary teeth to create indentations into the material. The stud on the transfer fork should project

FIGURE 9–11 Whip-Mix average-axis facebow being inserted into ear openings.

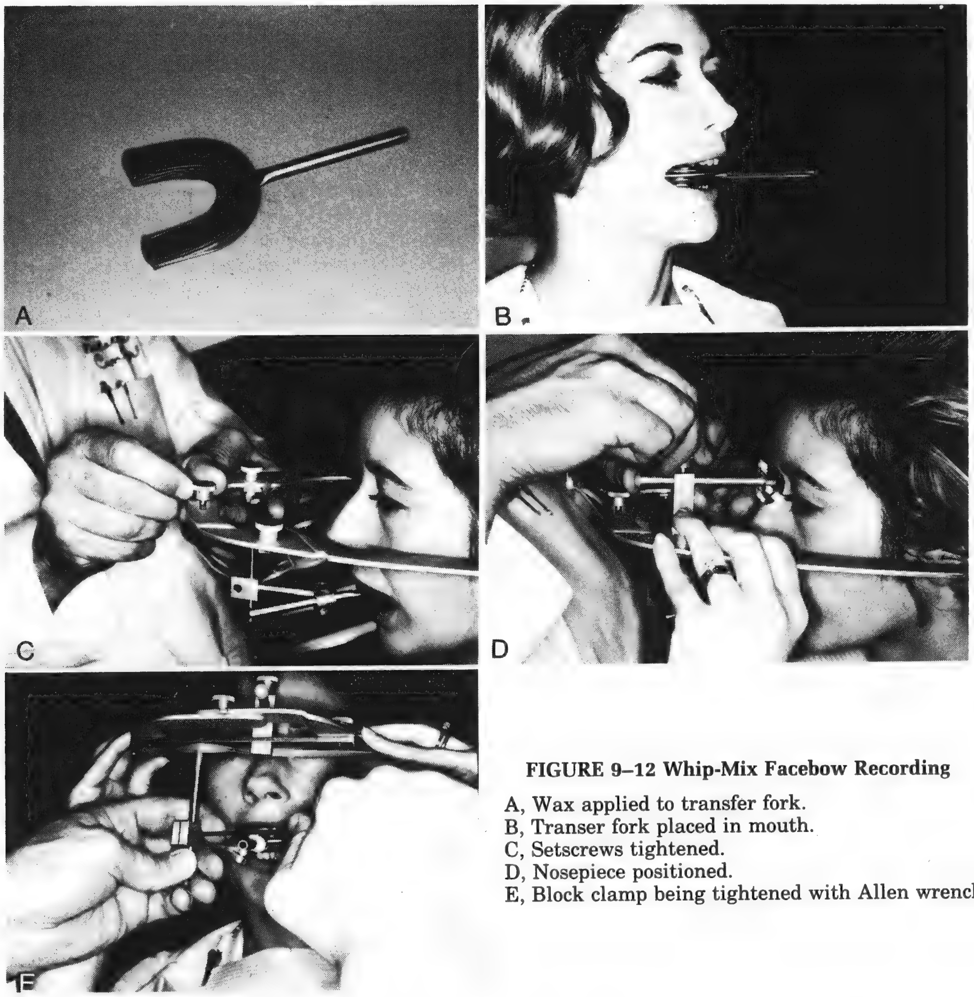


FIGURE 9–12 Whip-Mix Facebow Recording

A, Wax applied to transfer fork.
B, Transer fork placed in mouth.
C, Setscrews tightened.
D, Nosepiece positioned.
E, Block clamp being tightened with Allen wrench.

straight forward and be approximately parallel to the plane of occlusion. The mandibular teeth can then be closed into the material on the underside so that the relationship of the fork to the upper teeth is maintained (Fig. 9–12B). The fork is removed from the mouth and checked for completion of marking. If the maxillary teeth have been forced into the coating material beyond their heights of contour, the wax (or compound) should be trimmed away, leaving registrations of only cusp tips and incisal edges, so that a visual check can be made of the accuracy with which the material contacts both the patient's teeth and the maxillary cast. The tooth indentations may be refined with a thin layer of zinc oxide and eugenol impression paste if maximal accuracy is sought.

Facebow Adjustment

The setscrews and toggles are loosened, and the facebow is positioned so that the plastic projections fit into the ears. The patient is instructed to grasp the side arms of the facebow and to bring the facebow inward and forward firmly but without causing discomfort. The universal toggle is slipped over the stud of the transfer fork, which has been immobilized by having the patient close the teeth into the imprints in the wax or compound. The setscrews are then tightened (Fig. 9–12C). The nosepiece is placed on the cross arm of the facebow, and the convex portion is brought into contact with the point nasion. With the facebow still being held in a forward position by the patient, the nosepiece is locked in place by its setscrew (Fig. 9–12D). The universal toggle is then tightened with an Allen wrench.

The final step in assembling the facebow and the transfer fork is to tighten firmly the block clamp on the vertical rod (Fig. 9–12E). For use with the model 8500 Whip-Mix articulator, the scale on the anterior aspect of the facebow is read to ascertain the intercondylar distance setting for the articulator, which may be small, medium, or large. When the Model 8300 Whip-Mix articulator is used, this notation is not needed, since this instrument has a fixed intercondylar distance. The setscrew on the nosepiece is loosened, and the nosepiece is removed from the facebow. The three setscrews on the facebow are loosened, the patient is instructed to open the mouth, the projections are removed from the patient's ears, and the facebow is removed from the head.

Mounting the Maxillary Cast on the Whip-Mix Articulator

The incisal guide pin is removed from the upper member of the articulator to allow attachment of the facebow. If applicable to the articulator model being used, the intercondylar distance setting of large, medium, or small is used to move the condylar elements on the lower member of the articulator into the appropriate threaded fittings. The condylar guides on the upper member are adjusted to the corresponding setting by either adding or removing the spacers that are on the condylar guide shafts. No spacers are used for a small setting, but one spacer is placed on each side for medium, and both spacers on each side for the large setting.

The setscrews on the facebow are loosened, and the facebow is opened. The holes on the medial surfaces of the plastic ear projections are placed over the pins that jut from the lateral surfaces of the condylar guides. The anterior portion of the upper member of the articulator is allowed to rest on the crossbar of the facebow, and the three setscrews on the upper surface of the facebow are tightened. The toggles of the facebow are allowed to rest on the incisal guide table (Fig. 9–13A).

The maxillary cast is placed into the tooth depressions on the upper surface of the transfer fork. To overcome sag resulting from the weight of the cast and mounting material, a cast support may be placed between the undersurface of the transfer fork and the lower member of the articulator. The cast is attached to the upper mounting plate, using fast-setting low-expansion plaster or stone (Fig. 9–13B). When the luting agent has set, the facebow may be removed from the articulator.

Hanau and Dentatus Average-Axis Facebow Recording

The facebow transfer fork is prepared in a manner similar to that described for the Whip-Mix facebow. An acceptable method of finding an average axis in this case is to locate a point 13 mm anterior to the external auditory meatus along a line extending from the upper portion of the tragus to the corner of the eye (Fig. 9–14A, B). The third point of reference is usually the lowermost point on the bony rim of the orbit, but for safety a point is marked on the side of the nose at this level to prevent eye damage should the facebow be bumped.

The facebow is assembled on the stud of the transfer fork with the axis rods aligned with the points designating the average axis. The axis rods are adjusted to be equidistant from the side arm of the facebow by means of the built-in millimeter scale. The facebow is held in position over the marks on the skin by an assistant, while the operator tightens the clamp that holds the facebow to the transfer fork (Fig. 9–14C). The orbital pointer is placed against the mark on the nose and immobilized. The patient is asked to open the mouth, and the facebow assembly is removed from the face (Fig. 9–14D).

Mounting the Maxillary Cast on Hanau and Dentatus Articulators

The medial surfaces of the axis rods of Hanau facebows have been drilled to accept the axle of the articulator. The axis rods are set to be equidistant so that they fit just over the axle without springing the facebow. This positioning relates the axle of the articulator to the average axis of the patient. The support at the anterior aspect of the facebow and the incisal guide pin are adjusted to align the orbital pointer with the axis-orbital plane indicator on the articulator. The use of the mounting pin, instead of the incisal guide pin, often makes this adjustment simpler (Fig. 9–15A). The maxillary cast is then placed on the transfer fork and mounted as previously described (Fig. 9–15B).

Mounting Casts Using the Hinge Axis

A hinge-axis facebow relationship is required to mount the maxillary cast in a fully adjustable articulator. This relationship also can be applied to improve accuracy when using a semiadjustable articulator.

Hinge-Axis Location

The first step in the transfer of a maxillary cast to an articulator with an accurate relationship to the patient's hinge axis is to locate that axis. This is done by attaching a hinge-axis locator to the patient's lower jaw by either a universal (Fig. 9–16A) or a custom-made clutch. The

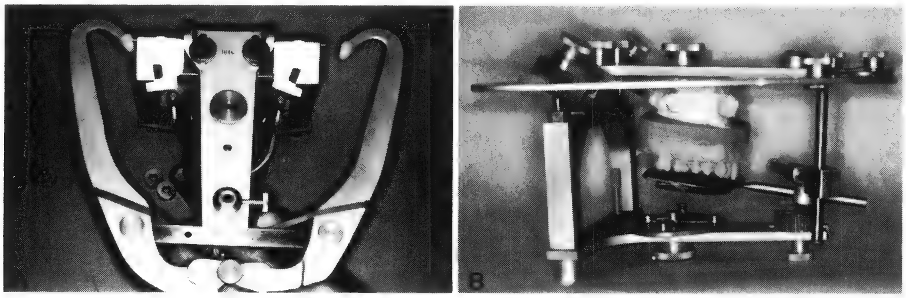


FIGURE 9–13 Whip-Mix Facebow Transfer

A, Plastic ear projections on facebow are slipped over pins projecting from condylar guides while the upper member of the articulator rests on facebow crossbar.
B, Cast attached to upper member of articulator with plaster.

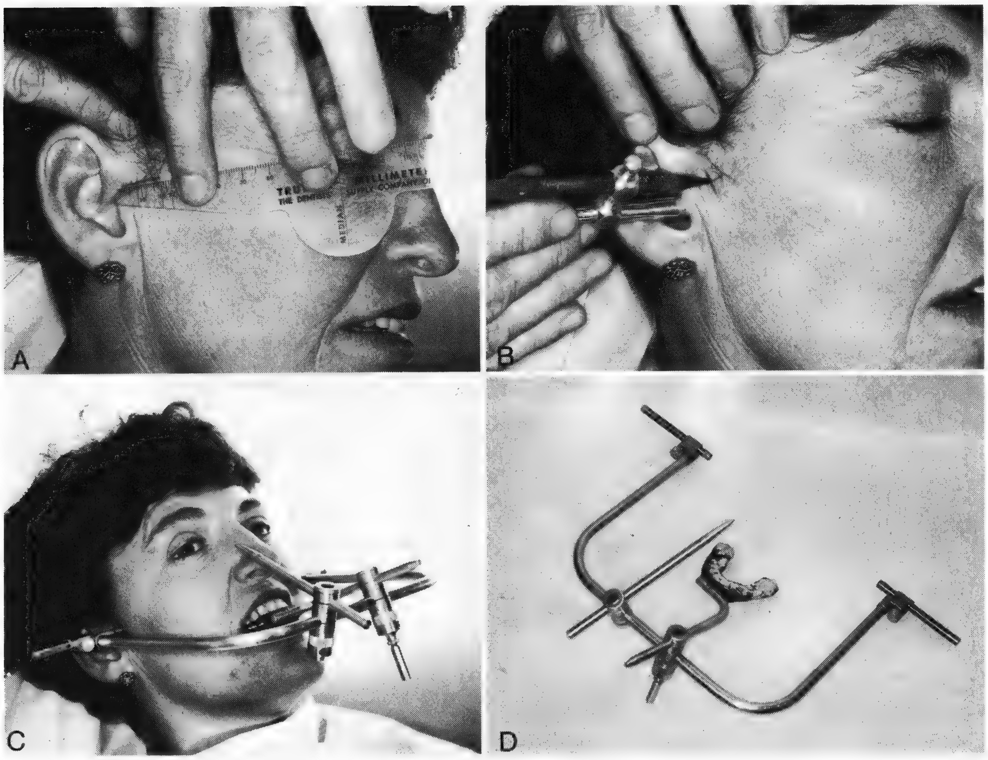


FIGURE 9–14 Hanau Facebow Recording

A, Tragus-eye line marked.
B, Marking point 13 mm along this line.
C, Facebow completely assembled on patient. Transverse rods are kept equidistant and over the previously located axis points. Note the mark on the side of the nose, which was projected from the lower rim of the orbit. The infraorbital pointer is located on this point.
D, Facebow removed from patient.

front arm of the axis locator is tightened over the clutch stud. The side arms of the hinge-axis locator are adjustable and are initially positioned so the axis locator pins are approximately over each condyle.

A maxillary clutch, or some form of head cap, is used to retain a metal flag carrying a piece of graph paper over each of the condylar regions to provide a background over which the operator may watch the movement of the axis locator pins (Fig. 9–16B). Lined paper pasted to the patient's skin is not considered to be suitable, since movement of the tissues will be transferred to the paper, making close observation of the axis

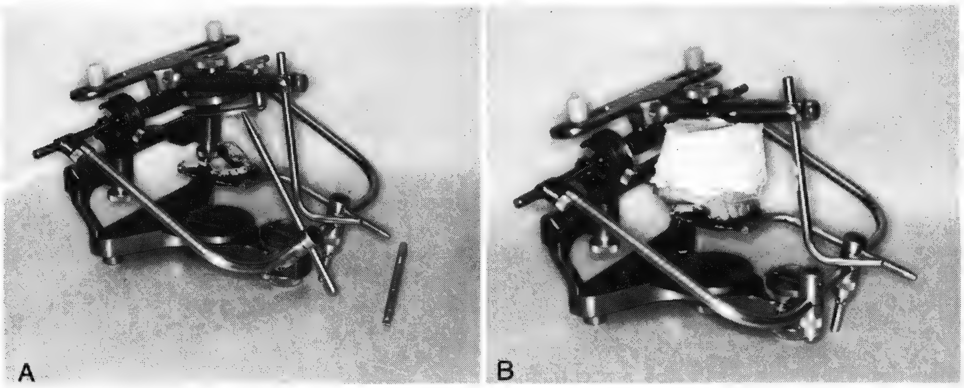


FIGURE 9–15 Hanau Facebow Transfer

A, Facebow on articulator with the infraorbital pointer aligned with the axis-orbital plane indicator. The mounting pin has been used instead of the incisal guide pin.
B, Cast secured with plaster.

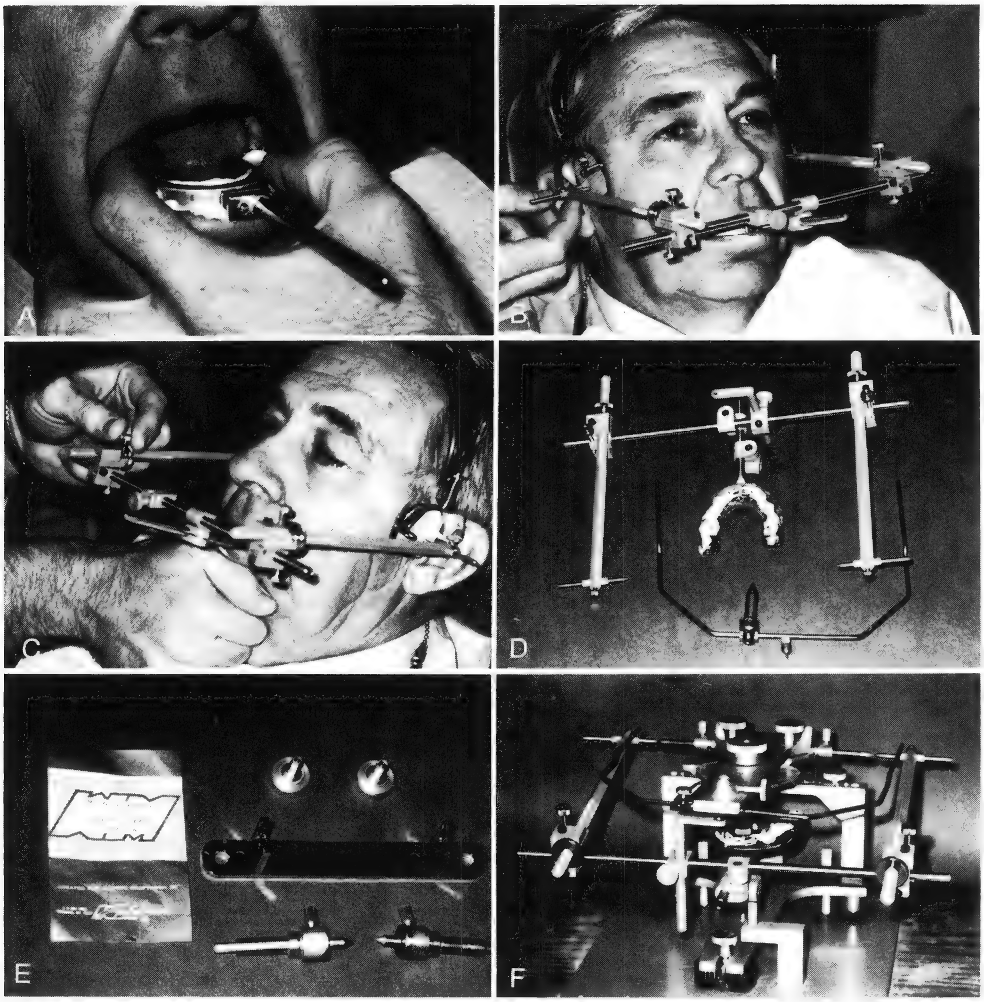


FIGURE 9–16 Hinge-Axis Recording and Transfer

A, Universal clutch filled with impression plaster and seated over mandibular teeth.
B, Apparatus assembled on patient.
C, Guiding the patient's opening and closing jaw movements while adjusting position of axis locator stylus.
D, Completed axis transfer record.
E, Whip-Mix transfer bracket and axis indicators.
F, Hinge-axis transfer recording on Whip-Mix articulator.

point impossible. The axis pins should be loose in the facebow side arm to prevent the sharp pin from marring the surface of the graph paper or hurting the patient if an inadvertent lateral movement is made. The mandible is guided into centric relation, and the operator then assists the patient in making hinge opening and closing movements while simultaneously watching the moving hinge-axis locator pins (Fig. 9–16C). Arcing of the pins indicates that they are not located over the axis. The location of the arc indicates the direction in which the instrument must be adjusted to make the pin coincide with the axis. The degree of arcing made by these pins shows how far they are from the axis. The larger the arc, the greater is the distance away from the axis. The axis has been located when the pin undergoes rotary movement without discernible arcing. The procedure is repeated for the other side. While the axis is being located, the patient may be seated in any position that is comfortable for the operator.

In order to make a facebow transfer, the axis location, at least temporarily, must be marked on the surface of the skin. For the soft tissues to be in a passive state during marking, the patient must sit upright in the dental chair, with the head out of the headrest. The flags carrying the graph paper are removed and, with the patient erect, the tips of the axis locator pins are coated lightly with graphite from a soft lead pencil or with a tattooing dye. The pins are pressed and twirled against the skin moderately to make a small mark. If a hinge-axis transfer is to be utilized in the future for this

particular patient, the axis should be permanently marked on the skin. This may be done by inserting a small amount of red tattoo dye, or India ink, into the deep layers of the skin with a sterile 27-gauge anesthetic needle or a special three-pronged tattooing needle.

Axis-Orbital Plane

The level of orbitale (the lowermost point on the bony rim of the orbit) is marked on the side of the nose to supply the third point of reference so that time after time the patient's casts may be fastened to an instrument in a definite reproducible relationship. One method for locating this third point is to project a line from the axis point to the lower rim of the orbit as found by palpation. Another acceptable method is to measure a distance 2⅛ inches from the incisal edges of the maxillary anterior teeth. The plane formed by the two axis points and the orbital point is referred to as the axis-orbital plane. This plane of reference, when used to make repeated and identical mountings of maxillary casts to dental articulators, eliminates the need to readjust an articulator for each set of casts mounted.

Axis Transfer Procedures

The facebow with which the hinge axis was located is also used to transfer the axis relationship to the articulator and to mount the maxillary cast. The first step in this procedure is to relate the transfer fork to the maxillary teeth. Both the superior and inferior surfaces of the transfer fork are coated with modeling compound. This is softened, and the fork is placed in contact with the occlusal surfaces of the maxillary teeth, with the stem of the transfer fork projecting in a line nearly horizontal to the axis-orbital plane and aligned with the midline of the maxillary arch. The patient is guided in a centric relation closure to imprint the plastic material with both the maxillary and mandibular teeth.

After the fork has been removed from the mouth, the compound should be trimmed so that only impressions of cusp tips and incisal edges remain in the material. Since the compound may distort, either while the imprint is being made or at the time the transfer fork is removed from the mouth, it is advisable that the indentations made by teeth be refined with a thin coating of zinc oxide and eugenol impression paste. If this is not done, the maxillary cast may not seat firmly in one position on the transfer form, and this will cause the mounting to be in error.

After the impression paste has set in the mouth, the fork is removed and all extraneous impression material is cut away. The fork is returned to the mouth and held in place by occlusion from the teeth. The facebow is then clamped to the transfer fork. With the patient in the same upright position as when the axis points were marked on the skin, the axis indicator pins of the facebow are adjusted until they coincide with the marks on the skin. The orbital pointer is added to the anterior portion of the facebow and, when aligned with the mark on the side of the nose, is locked in place. All parts of the facebow are tightened so that they cannot move during the mounting of the cast; alignment to the marks on the skin is rechecked, and the transfer bow is then removed from the patient (Fig. 9–16D).

Mounting the Maxillary Cast

With many articulators it is necessary to use a mounting stand when transferring the hinge-axis facebow to the articulator. The facebow is attached to the mounting stand and manipulated so that the axis-indicating pins are a few millimeters higher than the axis of the articulator. For the Whip-Mix articulator, a mounting bracket and adjustable axis indicators are substituted for the condylar spheres and condylar guides, respectively (Fig. 9–16E). The facebow is securely clamped in place to forestall movement. The back of the articulator is raised, usually by means of jackscrews located near the rear of the lower member of the instrument, until the axis points on the facebow coincide with the axis of the articulator.

The parts of the articulator that form its axis are adjusted equally outward to the two axis indicators on the facebow (Fig. 9–16F). Only by doing this can the axis of the articulator be made to coincide with the axis formed between the two points on the facebow, inasmuch as the points would be moved off the recorded axis if the pins on the facebow were moved. When the axis represented by the facebow and the axis of the articulator have been aligned, the articulator is clamped onto the mounting stand so that it will not move while the maxillary cast is luted to the upper member of the articulator.

The front of the upper member of the articulator is allowed to rest on the axis-orbital plane indicator. The maxillary cast is fitted carefully into the indentations of the maxillary teeth in the transfer fork and luted to the mounting plate of the upper member of the articulator with low-expansion impression plaster or dental stone.

Relating the Mandibular Cast to the Mounted Maxillary Cast

Once the maxillary cast has been mounted using either an average-axis or hinge-axis facebow transfer, the mandibular cast must be related to it and mounted in the articulator.

Accurate maxillomandibular tooth relationships can be obtained in two ways. A material may be placed between the teeth, the mandible may be guided in a closing movement until the teeth contact the recording material without opposing tooth contact, and the mandible may be held motionless until the recording material hardens. This centric relation record is then used to relate the maxillary and mandibular casts. The maxillary and mandibular casts can also be related using the existing maximal interdigitation of the teeth. Both techniques require casts that have accurately reproduced the occlusal surfaces, since the presence of nodules or voids on approximating aspects of the occlusal surface prevents accurate interrelationships.

Registering Centric Relation

A centric relation registration is used whenever it is vital to study or work with tooth contacts that occur when the mandible is in a terminal hinge position. In this relationship, it is possible to detect, study, and plan for elimination of centric occlusal prematurities by occlusal equilibration. It is also possible to fabricate restorations without creating occlusal prematurities.

Registrations are made by guiding the patient's mandible into a terminal hinge closure. They should always be made with the patient's teeth out of contact in order that the teeth have no deflecting influence. Also, it is recommended that three records be made, the second and third being used to check the accuracy of the first after the mandibular cast has been mounted on the articulator. All registrations must be carefully treated after removal from the mouth in order to avoid deformation.

A number of techniques and materials are well suited for obtaining centric relation registrations.

One method utilizes an anterior jig to hold the teeth slightly out of contact. The resin jig is formed around the maxillary central incisors and shaped so it forms a flat ramp with an upward lingual slope (Fig. 9–17A). The ramp thickness and form is adjusted to allow even contact with the mandibular incisors while keeping the posterior teeth slightly out of contact. Malleable metal* is shaped so it conforms to the arch with anterior projections that allow it to be suspended over the mesial aspect of the canines and to hang vertically between the opposing teeth when the patient is in a supine position. The incisor area is not covered to allow space for the anterior jig (Fig. 9–17B, C). The metal is coated with zinc oxide–eugenol wherever opposing posterior teeth will be located and suspended over the canines (Fig. 9–17D). The mandible is guided in centric relation until the mandibular incisors contact the anterior jig and is held motionless until the material sets (Fig. 9–17E, F).

Gauze bibs supported by a plastic frame† can be used

*Ash's Soft Metal, Number 7, Claudius Ash, Niagara Falls, NY 14304.
†Super Bite disposable trays, Harry J. Bosworth Co., Skokie, IL 60076.

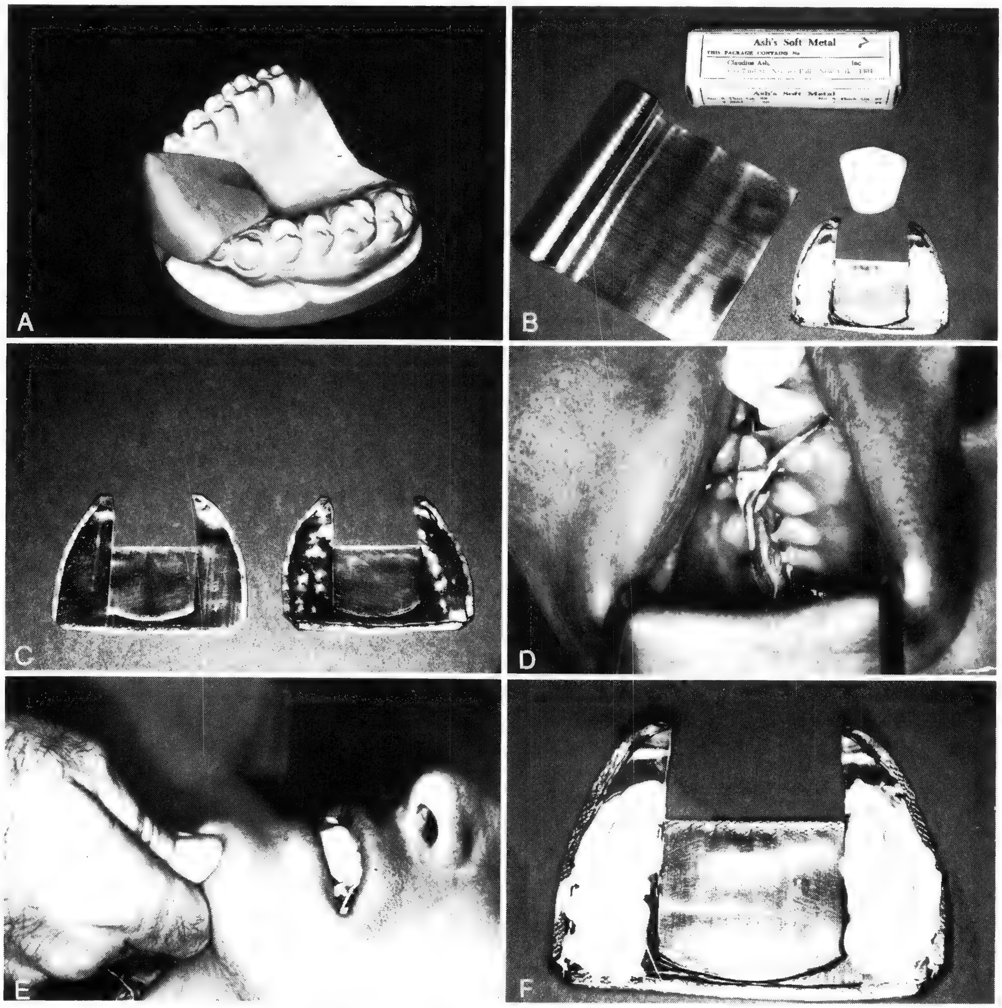


FIGURE 9–17 Anterior Jig Technique

A, Resin jig formed on cast.
B, Materials for making centric relation record.
C, Left, metal carrier cut to size of arch. Right, carrier has been placed in mouth, and patient has been allowed to bite into metal so it conforms to arches.
D, Carrier suspended over canines with jig in position and patient in supine position.
E, Mandible guided into contact with anterior jig.
F, Completed centric relation record.

as an alternative to custom-made metal forms to support and carry zinc oxide-eugenol into the mouth (Fig. 9–18). These frames are supplied in two halves, which must be connected together so that they are compatible with arch width. The plastic frames can be snapped together or luted together with sticky wax in the proper position. These trays should be first tried in the mouth to make certain that no interference occurs with centric relation closure.

Puttylike elastomeric impression materials and autopolymerizing resins can also be used for interocclusal records. However, resin shrinks on polymerization, and when used in significant bulk it should be relined with a zinc oxide-eugenol paste to attain maximal accuracy. Rubber and resin materials can be used alone, since they do not require another material for support. They are mixed and molded into the form of bars, which are then placed on each side of the arch. The mandible is guided into a closing movement and then held motionless until complete setting of the material has occurred (Fig. 9–19).

Whenever the number of missing teeth makes it difficult to stabilize the casts in the registration, the record must be made in conjunction with a stabilized baseplate. To relate properly to both cast and patient, the baseplate must be fabricated on the cast to be mounted. It should be made of autopolymerizing resin with an overlying wax rim and may incorporate stainless steel wire clasps to improve stability (Fig. 9–20A–D). The height of the wax rim should be such that when the mandible is closed the wax is slightly out of contact with the opposing cusps or another occlusion rim. Zinc oxide–eugenol paste is used over the wax to record the occlusion (Fig. 9–20E, F).

A unilateral interocclusal record made over only the prepared teeth can sometimes be used in place of a bilateral record. However, this procedure requires an adequate number of uniform noninterfering tooth contacts so that the mandible is guided to the proper position by tooth contacts occurring on the remaining unprepared teeth. The unilateral record is used to capture the proper occlusal reduction space and to aid the nonprepared teeth in mesiodistally orienting the casts as they are mounted in the articulator.

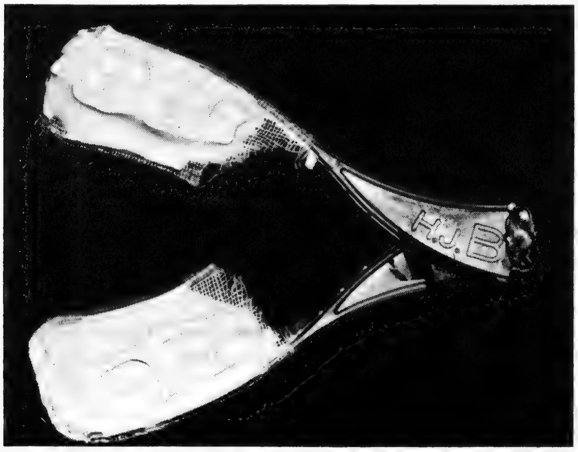


FIGURE 9–18 Plastic trays attached with sticky wax to conform to arch and zinc oxide–eugenol record obtained.

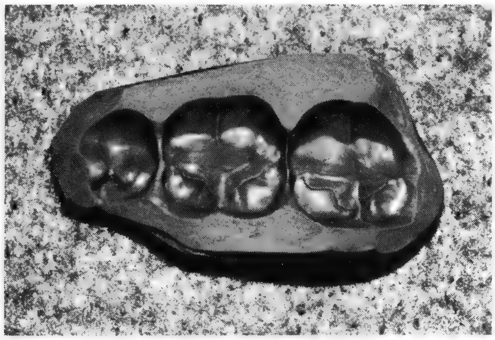


FIGURE 9–19 Interocclusal record obtained with poly (vinyl siloxane) impression material.

Recording Maximal Interdigitation

The maxillary and mandibular casts can be mounted in a position of maximal intercuspation by holding them in contact with each other and using the existing interdigitation of the teeth. This type of mounting requires a sufficient number of opposing teeth that interdigitate well to provide accurate three-dimensional orientation. Also, the existing occlusal relationship must be deemed acceptable, since the prosthesis will be fabricated in this position.

The previously described gauze bib frames (see Fig. 9–18) are also well suited for recording maximal interdigitation. The gauze bibs are coated with a thin layer of zinc oxide and eugenol paste and returned to the mouth, and the mandible is closed into a maximal interlocking location. The patient is instructed to hold the teeth lightly in contact while the impression paste sets. After the paste has set completely, the bite frame is removed. Excess paste that might interfere with proper seating of the casts is trimmed away with a sharp knife. Rubber impression materials and autopolymerizing resins also can be used in place of the bite frame and paste.

If the remaining teeth are not well distributed, the zinc oxide and eugenol registration material must be used on stabilized baseplates with wax occlusion rims. When the edentulous areas are confined to two opposing quadrants, one half of the bite frame may be used against the occluding area, while occlusion rims are used for the edentulous side.

A unilateral interocclusal record may be made when an adequate number of properly interdigitating teeth are present in other areas of the arch.

Attaching the Mandibular Cast to the Articulator

Whether centric relation registrations or records denoting maximal occlusion are utilized, the procedures used to mount the mandibular casts are the same (Fig. 9–21). The incisal guide pin of the articulator is set to give the needed height. If a centric relation registration is to be used, the pin should be adjusted to increase the opening to compensate for the thickness of the recording material. For mounting in maximal interdigitation, the incisal guide pin is set at zero. The articulator with the maxillary cast in place is inverted on the working surface. The occlusal registration is fitted to the maxil-

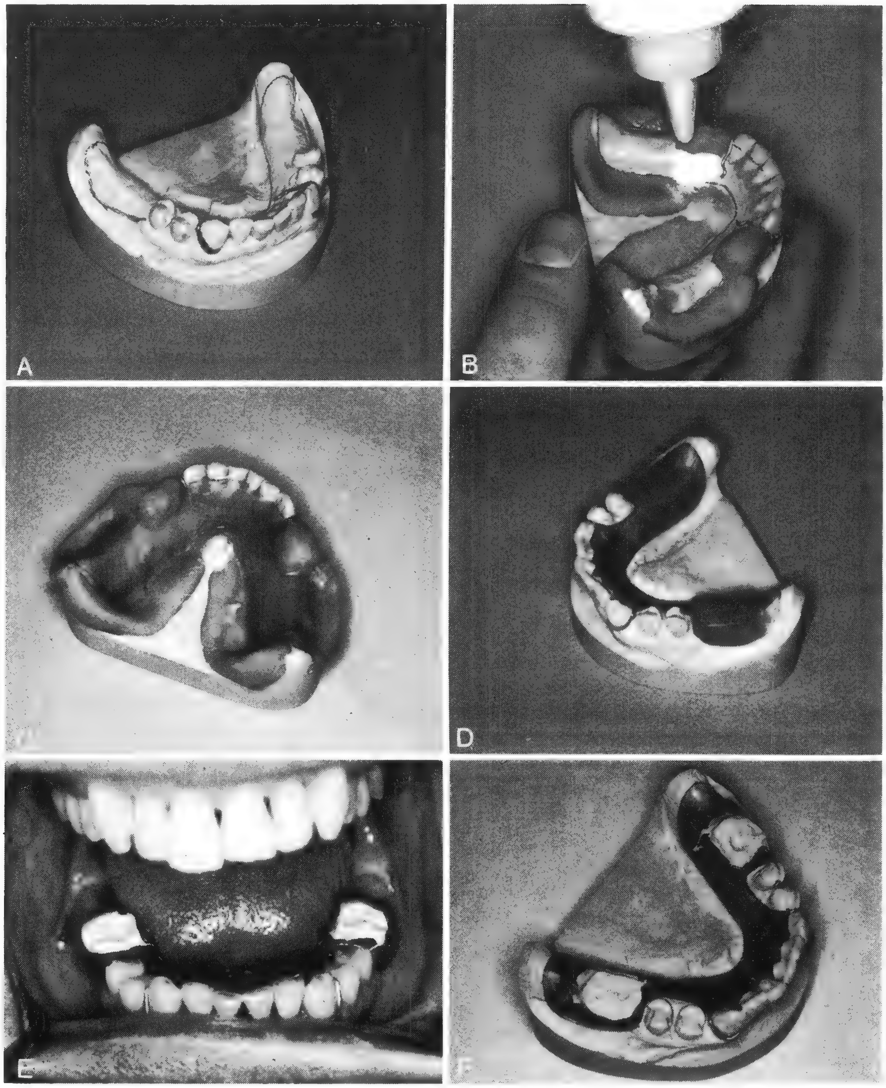


FIGURE 9–20 Fabricating Stabilized Baseplate

A, Working cast that has been coated with resin-separating medium.
B, Modeling clay used to control extent of resin flow and to cover prepared teeth. Resin being applied.
C, Application of resin completed.
D, The trimmed resin baseplate built up with wax in edentulous areas.
E, The occlusal registration is obtained using zinc oxide–eugenol impression paste spread over the wax rim.
F, Registration placed on working cast.

lary cast, and the mandibular cast is placed into it. The mandibular cast is held by hand or secured with sticky wax as it is affixed to the lower member of the articulator with a fast-setting low-expansion plaster or stone.

METHODS OF RECORDING MANDIBULAR MOVEMENT

Several methods are available for recording mandibular movements so dental articulators can either simulate or duplicate the recorded movements. One commonly used method is the intraoral interocclusal record made in wax. Intraoral tracings have also been used as guides for setting dental articulators. The most sophisticated way at the present is one in which the data are derived from extraoral mandibular recordings, also called pantographic tracings, so that the instrument can be set to a fine degree of accuracy. This method is used with fully adjustable articulators.

WAX ECCENTRIC INTEROCCLUSAL REGISTRATIONS

Semiadjustable instruments may be set quite satisfactorily with wax eccentric interocclusal registrations.

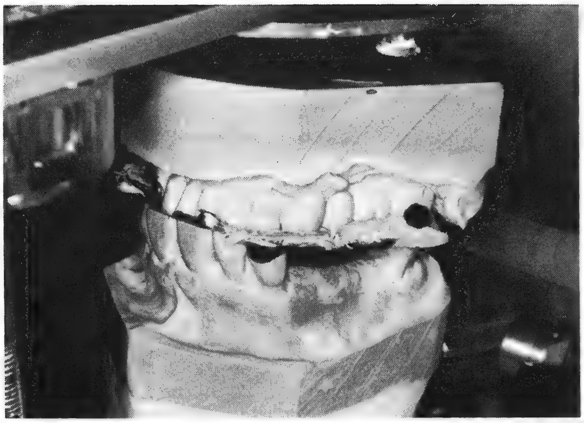


FIGURE 9–21 Mounting the mandibular cast. Cast in place in registration on inverted articulator. The casts have been joined to the registration with sticky wax to prevent movement during mounting procedures.

Aluwax* and Coprwax† are two of the many brands of wax available for this purpose. Aluwax can be purchased in a double thickness with gauze in the center, in a thick wafer, and in a regular sheet. The Coprwax Bite Wafer is horseshoe-shaped and is meant to be used as it is procured from the manufacturer. The wafer is about 5 mm thick and consists of two layers of wax with a layer of metal foil sandwiched between them. Coprwax is somewhat pliable at room temperature and may be used for registrations without being softened by warming.

Regardless of which wax is used, it should be trimmed so that there will be no impingement with the soft tissues. Using the diagnostic casts as guides, this must be done before the record is made in order to avoid later deformation of the record. The operator places the prepared wax in contact with the maxillary teeth (Fig. 9–22A), locating it so that there will be sufficient wax in the direction in which the excursion is to be made.

Right and left lateral records are used to set the condylar inclination and the degree of sideshift that occurs during lateral movement. A protrusive record is made also, since the protrusive path of the condyle is not often the same as its lateral path.

*Aluwax Dental Products Co., Grand Rapids, MI 49508.
†Columbus Dental, St. Louis, MO 63188.

Protrusive Interocclusal Wax Record

The protrusive registration is made by guiding the mandible forward until the lower anterior teeth are even with or just beyond the incisal edges of the maxillary incisors (Fig. 9–22B, C). The mandible is then guided closed until the teeth indent the wax. The patient's teeth should not penetrate the wax to the extent that there is tooth-to-tooth contact, because such contact may cause rocking of the mandible and a faulty record. The registrations most easily used are those that contain imprints of only the incisal edges and the cusp tips (Fig. 9–22D). Wax may have to be added to both sides posteriorly (Fig. 9–22A), so that uniformly shallow indentations are produced in all areas of the registration.

Lateral Interocclusal Wax Records

To obtain lateral registrations, the mandible is guided into both right and left working movements. The body of the mandible should be supported on the side of the advancing condyle, to direct the force both upward and in the direction of the motion of the mandible. This maneuver makes certain that the condyle maintains contact with the articular surface and that the full sideshift is attained. The recordings and articulator settings need conform only to the functional range of the patient. Therefore, the lateral registrations usually are taken with the mandibular teeth just beyond an edge-to-edge relationship.

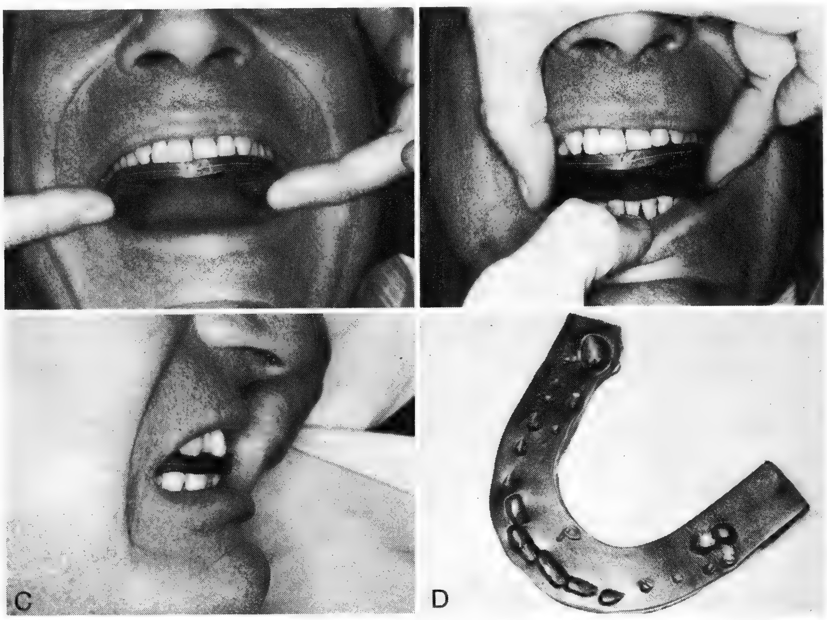


FIGURE 9–22 Protrusive Interocclusal Wax Record

A, Positioning the recording wax against the maxillary teeth. An extra thickness of wax has been added posteriorly to ensure even contact of all teeth.
B, Patient's jaw moving forward against pressure from the thumb.
C, The anterior teeth in an edge-to-edge relationship.
D, The protrusive record in wax.

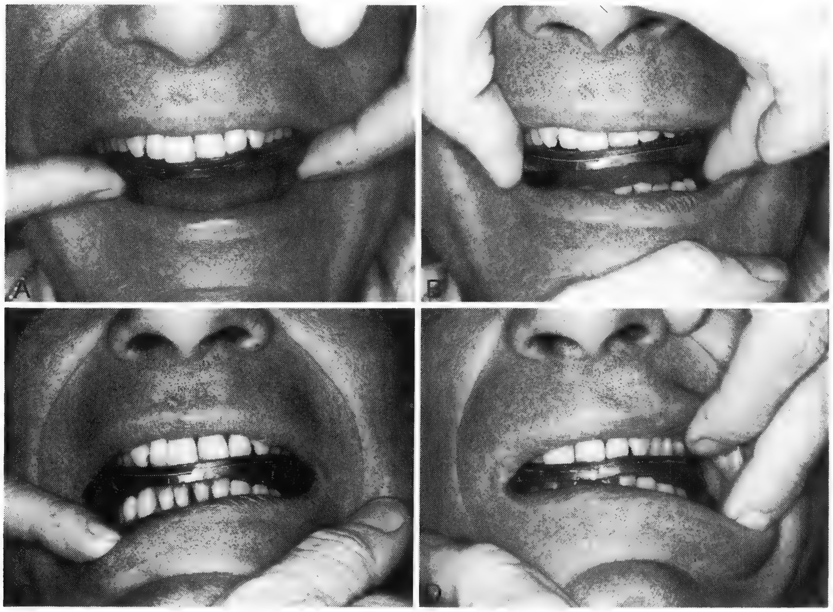


FIGURE 9–23 Lateral Interocclusal Wax Records

A,B, Positioning the preindented wafers against the maxillary teeth.
C,D, Guiding the mandible to place the lower teeth into the preformed indentations. The operator's index finger is supporting the inferior border of the mandible to ensure that the most superior position of the condyle is maintained. The thumb is used to exert some force in the direction in which the mandible is to move. This guides the jaw in the proper direction and helps incorporate maximal sideshift into the movement.

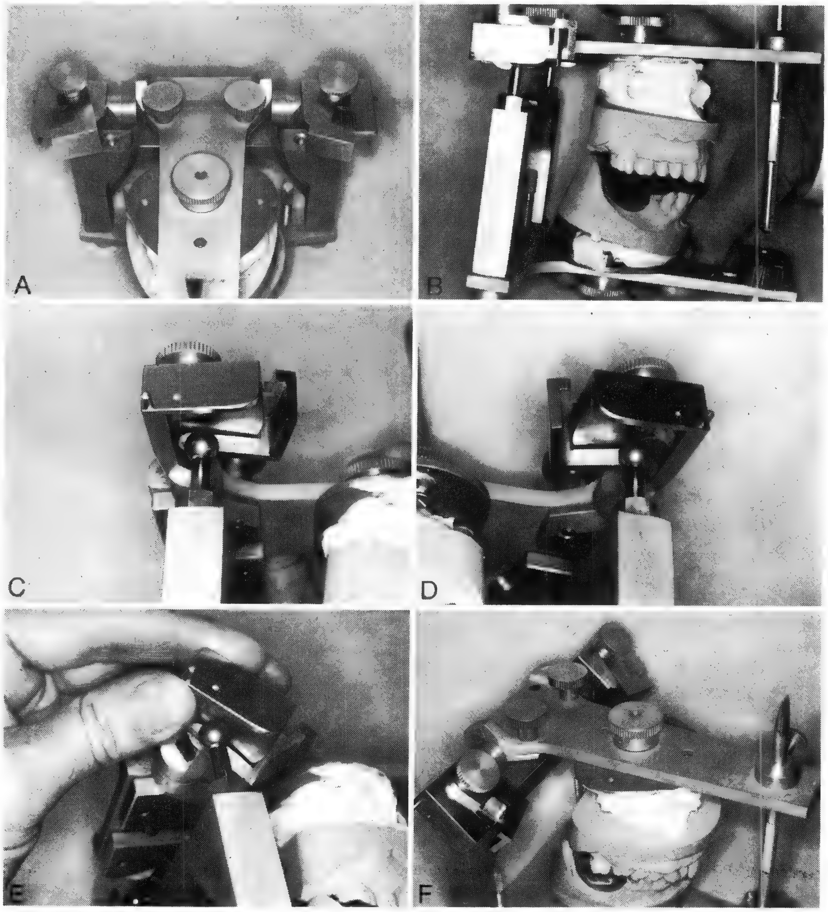


FIGURE 9–24 Setting Articulator for Protrusive Movement

A, Sideshift guides opened to approximately 15 degrees.
B, Condylar inclination near zero and protrusive record in place.
C,D, Lack of contact of condylar spheres against condylar guides.
E, Rotating right condylar guide to a position of contact with the sphere.
F, Condylar guides set to protrusive path.

These wafers are taken to the mouth and positioned on the maxillary teeth (Fig. 9–23A, B); the patient is guided until the mandible is just beyond an edge-to-edge relationship (Fig. 9–23C, D). With the mandible in the proper position, the patient is asked to close the jaw just enough to create shallow cusp tip and incisal edge indentations.

Setting the Whip-Mix Articulator to the Protrusive Record

To set the Whip-Mix articulator using the protrusive wax registration, the sideshift guides are first set at about 15 degrees (Fig. 9–24A) so that the condyles are free to move laterally a little in case any sideshift has been incorporated in the protrusive recording. The condylar guides are loosened and adjusted to near zero (Fig. 9–24B, C, D). With the protrusive registration interposed, the two halves of the articulator are held together so that the teeth are properly oriented into the wax. Care must be taken not to rock the articulator halves and distort the registration. Each condylar guide is rotated downward (Fig. 9–24E) until it makes contact with its condylar sphere. The holding screws of the condylar guides are tightened, and then both condylar inclinations can be read from the sides of the upper arm of the articulator and recorded (Fig. 9–24F).

Setting the Whip-Mix Articulator to Lateral Registrations

The condylar guides are again returned to near-zero positions (Fig. 9–25A), and the sideshift guides are opened completely. One of the lateral registrations is selected (Fig. 9–25B) and placed between the mounted casts. Again the condylar guide is rotated downward until contact is made with the condylar sphere, after which its holding screw is tightened (Fig. 9–25C, D).

The sideshift guide is then rotated laterally until it makes contact with the medial aspect of the advancing condylar sphere, and its holding screw is tightened (Fig. 9–25E, F). This process is repeated using the other lateral registration to set the opposite condylar guide and sideshift mechanism. The angle settings of both the condylar guides and the sideshift guides are read and recorded. If a discrepancy exists between the condylar inclinations in the protrusive as compared with the lateral reading, the smaller number of degrees can be selected or changes may be made in these settings while the articulator is in use to conform with the particular movement the articulator is simulating.

Adjusting the Hanau and Dentatus Articulators

The same principles are applied when obtaining interocclusal records for the Hanau and Dentatus articu-

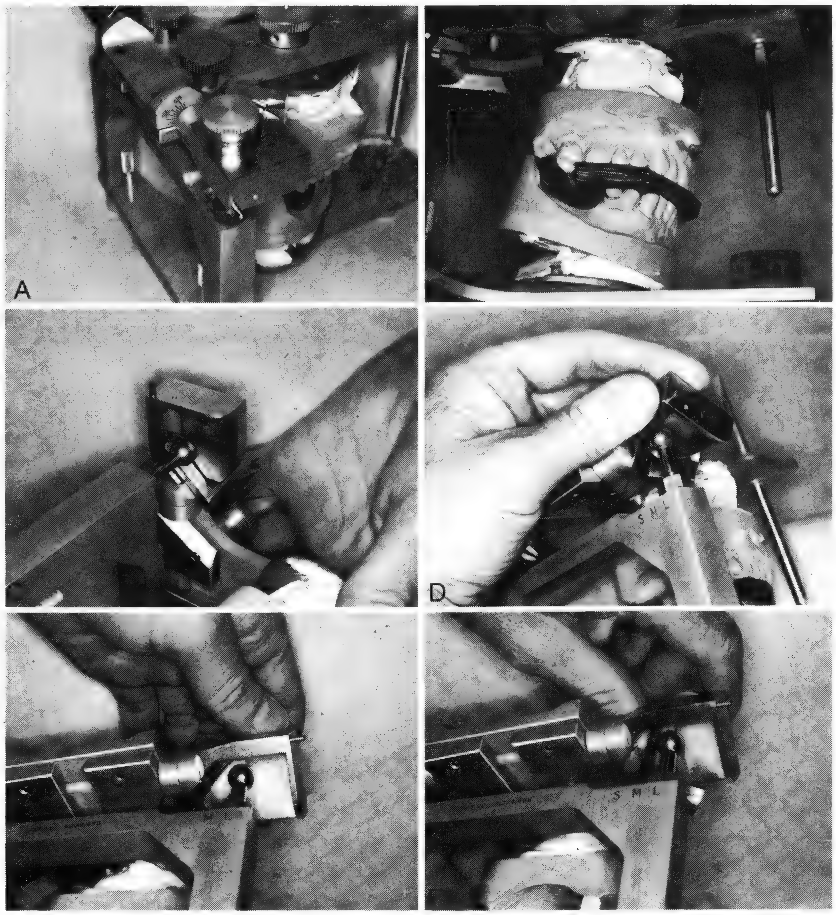


FIGURE 9–25 Setting the Whip-Mix Articulator to the Left Lateral Interocclusal Record

A, Right condylar path set to horizontal position. The lateral shift guide is fully open.
B, Left lateral record in place between the casts.
C, Condylar guide fails to contact sphere.
D, Condylar guide being rotated into contact with sphere.
E, The sideshift guide remains away from the sphere after setting and locking of the condylar guide.
F, The sideshift guide is rotated into place against the sphere and locked in place.

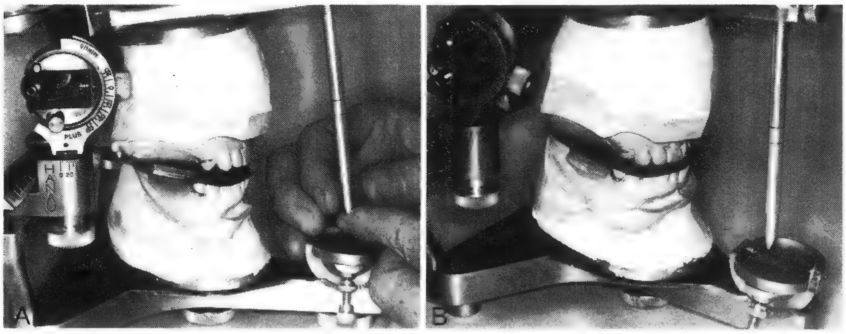


FIGURE 9–26 Adjusting the Hanau Articulator to the Protrusive Record

A, Protrusive record in place. The post is rotated inward 15 degrees, and the condylar guidance is nearly horizontal. Note that the maxillary anterior teeth do not fit into their indentations.
B, The condylar guides have been rotated downward to fit the teeth on the casts into their respective imprints.

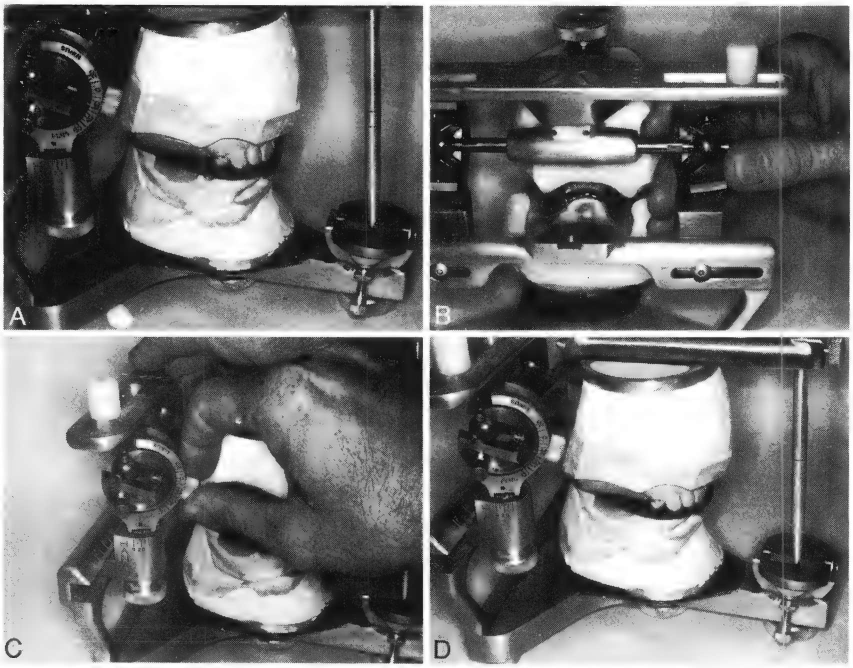


FIGURE 9–27 Adjusting the Hanau Articulator to the Left Lateral Record

A, Wax record placed between casts.
B, Rotating the post to make contact between the condylar sphere and the shoulder on the articulator axle.
C, Adjusting condylar inclination.
D, Articulator set for left lateral excursion.

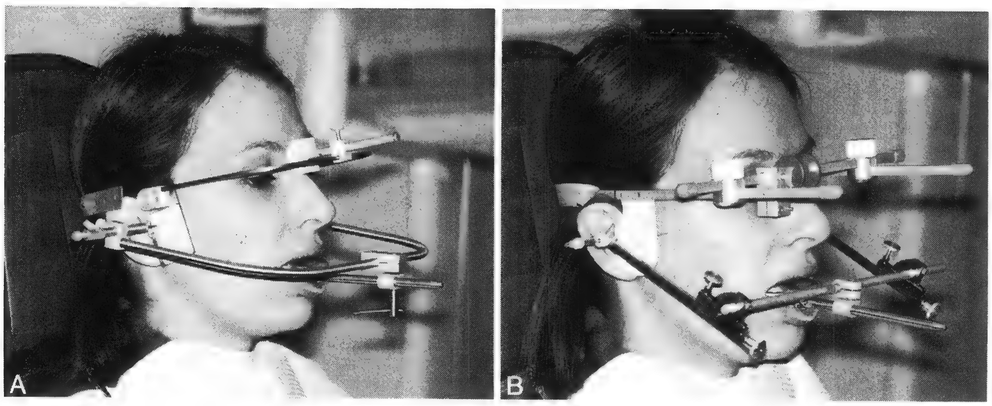


FIGURE 9–28 Simplified Mandibular Motion Analyzers

A, Whip-Mix Quick Set Recorder.
B, Panadent Quick Analyzer.

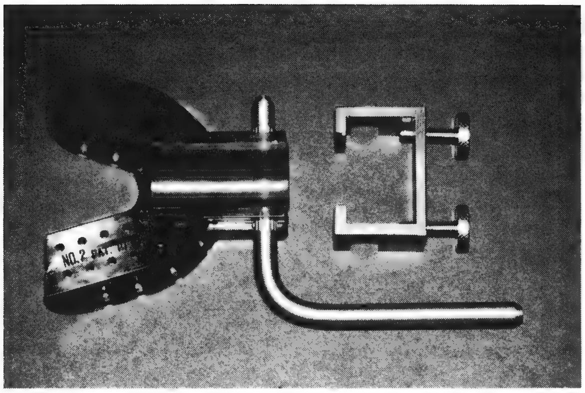


FIGURE 9–29 Panadent Disposable Plastic Clutch.

lators as have been discussed in conjunction with the Whip-Mix articulator.

The condylar posts are rotated inward 15 degrees, because of the possibility that the patient may have failed to execute a pure protrusive movement. The protrusive registration is placed between the maxillary and mandibular casts (Fig. 9–26A), and the condylar guides are rotated to find the inclinations at which the teeth on the casts best interdigitate into indentations in the wax record (Fig. 9–26B). The degree of condylar inclination on each is noted and recorded.

One of the lateral registrations is placed between the casts (Fig. 9–27A), and the condylar post is rotated until the shoulder on the axle of the articulator makes contact with the medial aspect of the condylar sphere (Fig. 9–27B). The condylar inclination is then readjusted so that the teeth on the cast interdigitate fully into the indentations of the wax record (Fig. 9–27C, D). The other lateral record is used to make the same settings for the opposite side of the articulator. When this procedure has been completed, the protrusive recording may be returned to the articulator and checked against the condylar settings that seem to be consistent with the lateral registrations. In many cases, close conformity is found. If not, the protrusive setting should be used for protrusive movements during diagnosis or treatment and the lateral settings for their appropriate excursions.

Simplified Mandibular Motion Analyzers

Semiadjustable arcon articulators*† with preformed condylar controls that allow immediate sideshift can be adjusted by using eccentric wax interocclusal records in the manner previously described. For optimal accuracy they may be used with simplified mandibular motion analyzers‡§ (Fig. 9–28). These analyzers measure the amount of immediate sideshift and trace the form of the protrusive condylar pathways.

The mandibular portion of the recording device is attached to the teeth by means of a disposable plastic clutch (Fig. 9–29) and oriented so that the styli are aligned with the axes. The maxillary portion with attached grids is then aligned in relation to the styli so that the form of the protrusive pathways will be contained within the grid boundary.

The mandible is guided into a working movement. The stylus on the nonworking side should move anteriorly 3 to 5 mm, at which point the immediate sideshift is measured (Fig. 9–30). The procedure is then repeated for the other side. A tracing of the protrusive movement is then made by attaching the provided pencil lead markers to the styli and using the lead to scribe a line on grid paper (Fig. 9–31).

The recorded amount of immediate sideshift is used to set that aspect of the condylar guidance. With the Whip-Mix Model 8300 articulator, the metal sideshift guide can be adjusted to allow varying amounts of immediate sideshift. The Panadent articulator uses analogs that allow different amounts of immediate sideshift in 0.5-mm increments from 0.5 mm to 2.5 mm. The condylar guidance analog that allows the proper amount of immediate sideshift is selected and placed in the upper member of the articulator. A special protractor, supplied by the articulator manufacturer, is superimposed over the protrusive tracing, and the angle of the eminentia is determined and set on the articulator.

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*Whip-Mix Model 8300, Whip-Mix Corp., Louisville, KY 40217.
†Panadent Articulator, Panadent Corp., Grand Terrace, CA 92324.
‡Quick Set Recorder, Whip-Mix Corp., Louisville, KY 40217.
§Quick Analyzer, Panadent Corp., Grand Terrace, CA 92324.

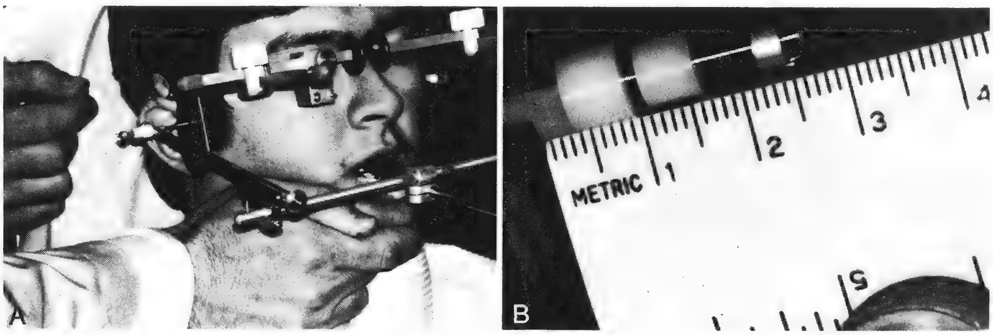

FIGURE 9–30 Recording Immediate Sideshift

A, Left working movement being made to accomplish right-side stylus movement of 3 to 5 mm.
B, Amount of immediate sideshift measured.

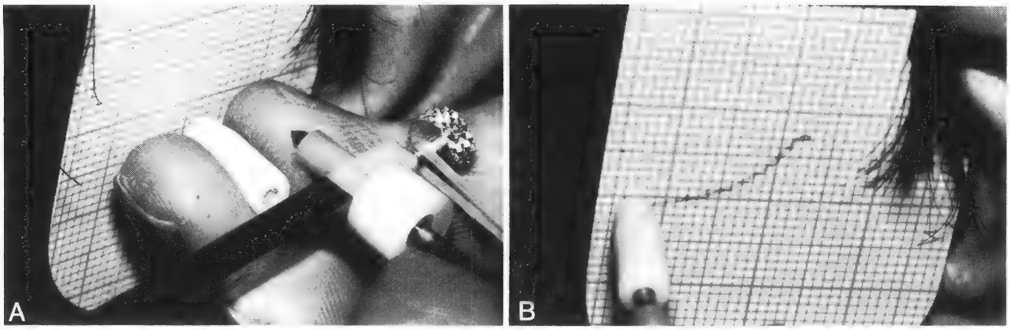

FIGURE 9–31 Recording Protrusive Condylar Pathway

A, Pencil point being attached to metal stylus.
B, Curvature of protrusive pathway recorded.

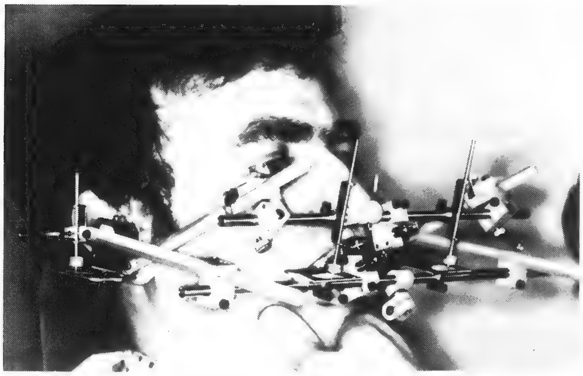

FIGURE 9–32 Stuart Gnathological Recorder.

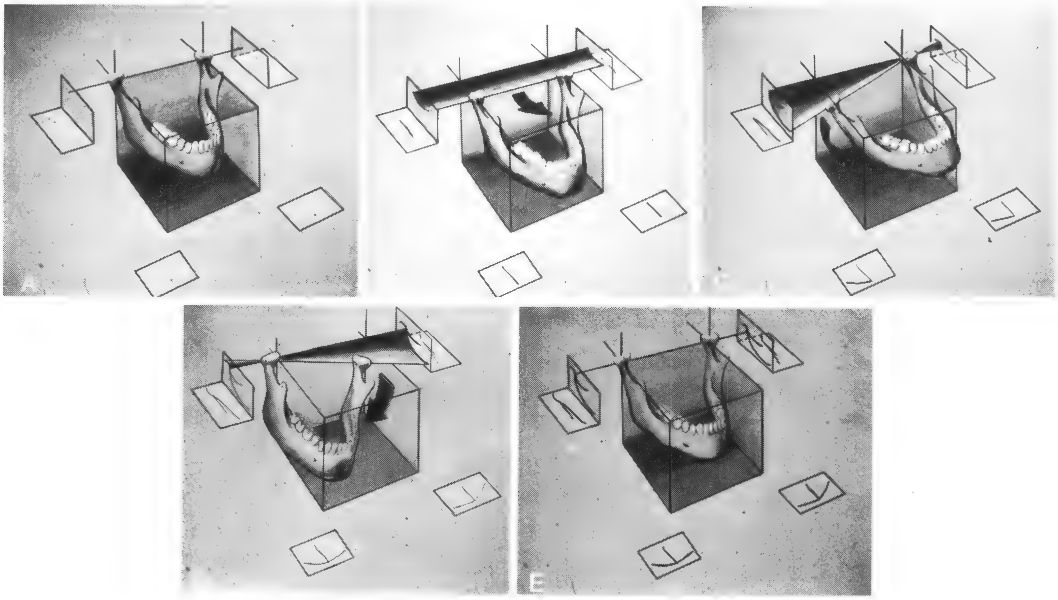

FIGURE 9–33 Diagrams of Lines Scribed During Mandibular Recording

A, Mandible in centric relation.
B, Protrusive movement completed and lines scribed on plates.
C, Left working movement completed.
D, Right working movement completed.
E, Completed tracing with mandible back in centric relation.
(Courtesy of The J. M. Ney Co.)

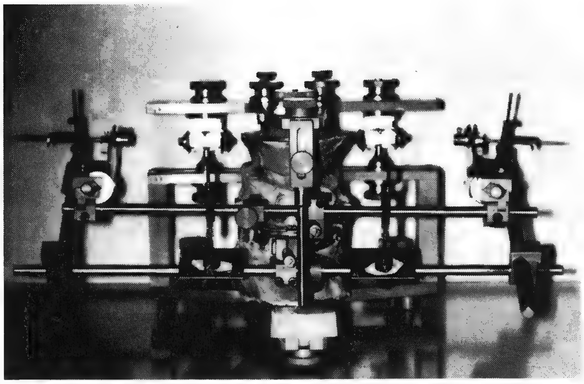

FIGURE 9–34 Stuart recording device attached to articulator.

Programming a Fully Adjustable Articulator

A recording of mandibular movements (protrusive) and right and left lateral is required to set a fully adjustable articulator. The recording device is composed of maxillary and mandibular portions, which are attached to clutches that have been cemented to the respective arches (Fig. 9–32).

Vertical and horizontal tracing plates are parts of the device. These are located laterally to each condyle. Also, two horizontal tracing plates are located anteriorly. Styli are brought into contact with these tracing plates and scribe lines on the plates during protrusive working and nonworking movements (Fig. 9–33). The styli are then lifted out of contact with the plates, and the lines are covered with transparent tape so they are protected from change. The upper and lower portions of the recording device are aligned in centric relation and affixed together. The entire device is then removed from the head and attached to the articulator in the same manner as with a hinge-axis transfer record (Fig. 9–34). Finally, the articulator is adjusted until the styli exactly follow the clinically scribed lines from the point of initiation to termination for each mandibular movement.

Recently, an electronic device* has been developed that has sensors attached to the styli (Fig. 9–35). When mandibular movements are produced, the device processes the information and prints out the articular settings, thereby avoiding the more time-consuming process of attaching the recording device to the articulator and manually adjusting the instrument until it follows the clinically scribed lines.

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*The Pantronic, Denar Corp., Anaheim, CA 92805.

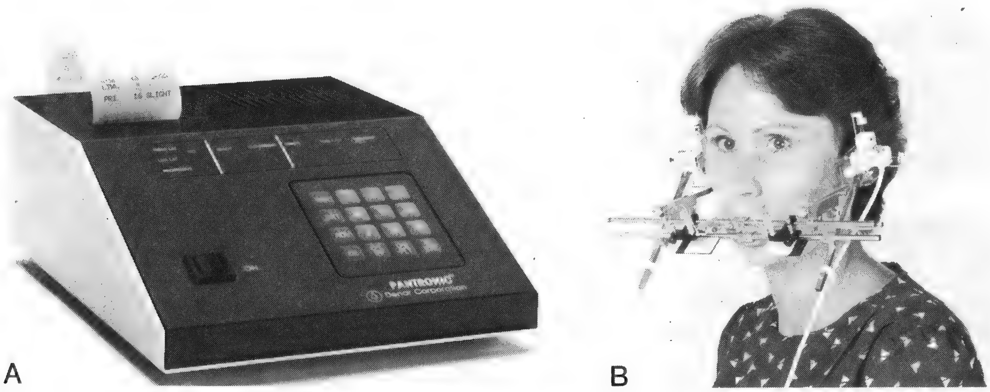

FIGURE 9–35
A, Denar Pantronic recording device. (Courtesy of Denar Corp.)
B, Instrument attached to patient.

10

Impressions and Records for Indirect Procedures

Obtaining an impression is the first step necessary to the indirect fabrication of a prosthesis. An impression is a negative reproduction of the prepared teeth, adjacent teeth, and surrounding soft tissue. Dental stone is mixed and poured into the impression, which, after hardening, produces a dimensionally accurate reproduction of the recorded areas. The prosthesis can then be fabricated indirectly on the stone cast.

TYPES OF IMPRESSION MATERIALS

Many types of impression materials are available, but this chapter discusses only those elastic materials commonly used to obtain impressions of prepared teeth: reversible hydrocolloids and elastomers.

REVERSIBLE HYDROCOLLOID IMPRESSION MATERIALS

Colloids are suspensions of molecules, or groups of molecules, in some type of dispersing medium. Colloid systems involve particles of a molecular size somewhere between the small particles of a true *solution* and the large ones present in a *suspension.* A colloidal solution may be referred to as a colloid *sol.*

A colloid has two components, the dispersed particles and the dispersion medium containing the particles. The term *hydrocolloid* indicates that the dispersion medium is water. An example of a hydrocolloid in the sol condition is common gelatin powder after it has been added to hot water. However, hydrocolloid sols possess the capacity to change into a jelly or *gel* under certain conditions. Thus, when the gelatin sol is placed in a refrigerator, a gel eventually results as the sol is cooled. The temperature at which this change from the sol state to a semisolid material takes place is known as the *gelation temperature.* Such a gel is *reversible* in characteristics, since it can again be liquefied (returned to the sol condition) by once again increasing the temperature above the liquefaction temperature. Thus the change from the sol to the gel, and vice versa, is essentially a physical effect induced by a change in temperature. The reaction may be summarized as:

$$\text{sol} \rightleftarrows \text{gel}.$$

Gelatin is unsuitable for an impression material, since the gel that is formed is weak, and the temperature required to bring about the formation of the gel is too low for comfort to the patient or for convenience. However, a substance known as agar, extracted from a certain type of seaweed, provides a suitable colloid as a base for dental impression materials. When suspended in water, the agar forms a liquid sol at temperatures that can be safely used in the oral cavity and also converts to a gel at a temperature slightly above that of the mouth.

The hydrocolloid impression material is placed around the prepared teeth in the sol condition. By means of water-cooled impression trays, the sol is converted into a gel that is firm yet elastic. The final gel, composed of a brush-heap arrangement of *fibrils* of agar enmeshed in water, is not chemically different from the original fluid sol. In essence, when in the sol condition the agar is suspended in water, whereas in the gel condition the water is suspended in the latticework of gel fibrils.

The basic constituent of reversible hydrocolloid impression materials is agar, which is present in a concentration of 8 to 15 per cent. Dental products are generally blends of several species of agar. However, the principal ingredient by weight (approximately 80 to 85 per cent) is water. Small amounts of borax are added by the manufacturer to increase the strength of the gel.

The presence of borax is detrimental to the impression material because it retards the set of the gypsum die material that is poured into the impression. If the surface becomes contaminated with the borax during setting, or with the gel itself (colloids are also retarders), a soft, powdery surface is likely to be formed on the final gypsum cast or die.

This problem can be overcome in two ways. (1) Before the impression is filled with stone, it may be immersed in a solution of 2 per cent potassium sulfate, or (2) a

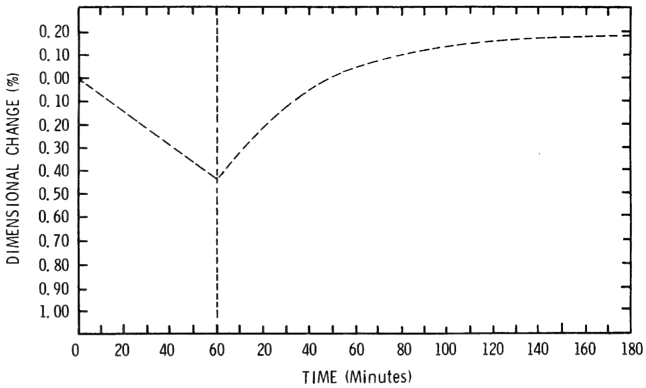

FIGURE 10–1 Linear contraction of a representative hydrocolloid in air (31 to 42 per cent relative humidity) and subsequent expansion in water. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982.)

plaster hardener or accelerator can be incorporated, by the manufacturer, into the material itself.

When the impression is removed from the mouth and carried into the air at room temperature, loss of fluid or syneresis usually starts immediately, with resulting shrinkage of the gel. Since the impression must be exposed to the air for sufficient time to construct the cast, some shrinkage is bound to occur. Furthermore, if the impression is immersed in water to replace the lost water, the swelling caused by imbibition does not restore the original dimension (Fig. 10–1). Consequently, the impression should be poured as soon as possible if the best results are to be obtained.

Various storage media, such as 2 per cent potassium sulfate or 100 per cent relative humidity, have often been suggested to prevent dimensional change. Results obtained for one dental hydrocolloid by storing impressions in these and two other media may be seen in Figure 10–2. These results are typical and indicate that a relative humidity of 100 per cent best preserves the normal water content. Unfortunately, however, there is some alteration in the water content and contraction even when the impression is stored in this environment. Furthermore, even if it were possible to preserve the water equilibrium, distortion would still be likely to occur during storage because of the relaxation of the internal stress that is always present in the impression. Thus, it is evident that there is no wholly satisfactory method for storing a hydrocolloid impression, and therefore it should be poured immediately.

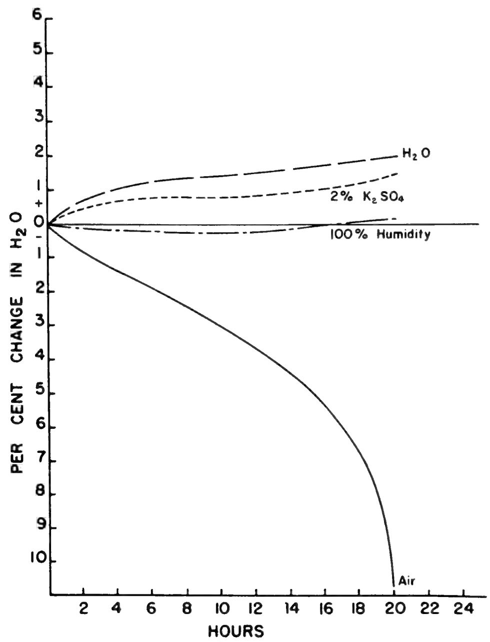

FIGURE 10–2 Percentage change in water content by weight of a hydrocolloid impression material in various storage media. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 122.)

However, there exist clinical situations that unexpectedly develop that prevent the die from being poured promptly. In such situations, as an alternative, the impression should be rinsed in tap water and wrapped in a paper towel saturated with water, and placed in a closed container. The container (a plastic bag or a humidor) should be kept closed until time is available to pour the impression. The impression can only be poured once to obtain an accurate cast. If multiple dies are needed, additional impressions must be obtained.

The stone must be completely set before the cast is separated from the impression, but prolonged periods of contact between the set stone and the hydrocolloid, such as overnight, must be avoided, since this can produce a chalky surface on the cast.

The "tear resistance" of an impression material is important. If this is high, the material is not likely to fracture and leave material that is essential for accurate reproduction behind in the gingival sulcus or interproximally. Hydrocolloids have relatively poor tear resistance in that thin extensions of material located subgingivally are susceptible to tearing when the impression is removed from the mouth.

Despite these apparent disadvantages, restorations comparable in accuracy to those obtained with elastomeric materials can be obtained when hydrocolloid is handled properly. In addition, hydrocolloid has advantages when compared with many elastomers. It is odorfree, clean, easy to handle, and does not require a custom tray. Also, it can be set up and ready for use without mixing and is less expensive.

ELASTOMERIC IMPRESSION MATERIALS

These materials are synthetic rubbers that are known technically as nonaqueous elastomers in order to differ-

entiate them from hydrocolloid. The ingredients are mixed and the elastic solid impression formed by chemical reaction.

The process of changing the elastomeric base, called a *liquid polymer,* into the final rubberlike material is generally referred to as curing or *polymerization.* A polymer can be thought of as a chemical compound built up from a number of single elementary units, which are linked together during the reaction. There are two basic types of polymerization reactions. One type, called *addition polymerization,* results in the formation of a polymer without the formation of any other chemical. In the second type, called *condensation polymerization,* other chemical compounds (called by-products) are produced that are not part of the polymer.

Chemically, there are four types of elastomeric polymers used for dental impression materials. The respective bases are a *polysulfide,* a *condensation polymerizing silicone,* an *addition polymerizing silicone,* and a *polyether.* Commercial products that are representative of the four types are seen in Figure 10–3. Any or all of these are frequently referred to as "rubber impression materials."

In addition to the four chemical types, many commercial products are available in different consistencies or viscosities. The four classes can be identified as (1) very high viscosity, which is actually of puttylike consistency; (2) high viscosity, which is referred to as "heavy body" or tray material; (3) medium viscosity, often called "regular"; and (4) low viscosity, referred to as "light body" or "syringe." The need for these four consistencies becomes apparent when we consider the clinical techniques used with the rubber impression materials.

Polysulfide Rubber

Composition, Chemistry, and Properties

Polysulfide rubber impression materials are supplied in two tubes (Fig. 10–3). One of these contains the polysulfide rubber base, which is liquid polymer made into a paste by the addition of certain powdered fillers. Accelerators and retarders may also be added as needed. The basic molecule of the polymer has a sulfhydryl group (SH) attached to a terminal carbon atom.

When this liquid polymer reacts with an appropriate chemical, usually lead dioxide (PbO_2), the polymer grows or lengthens by polymerization and thereby changes to an elastomeric solid. Sulfur is also employed to facilitate the reaction and to provide better properties. The polymer paste is usually white and is generally labeled as the *base.*

The second tube contains the sulfur and lead dioxide. Since both these substances are powders, a liquid plasticizer is added in order to form a paste. This paste is often labeled by the manufacturer as the "accelerator" or "catalyst." However, the paste should more properly be termed the *reactor,* since it contains the ingredient (PbO_2) that produces the reaction that forms the soft rubber. This paste is usually brown because of the lead dioxide. However, if an organic peroxide is used as a reactor, it may be another color. Such a mix is more pleasing esthetically and cleaner in handling.

The manipulation of these materials is discussed in detail later in this chapter. Proportionate amounts of the two pastes are placed on a mixing pad, usually by squeezing out equal lengths, and then mixed thoroughly with a spatula. The curing reaction begins when the mixing is started and continues in a progressive manner. The mix gains elasticity until a rubber material is formed that can be withdrawn over the teeth and undercut areas with a minimal amount of permanent deformation.

The properties of the four rubber base materials are summarized in Table 10–1. The polysulfides have a strong odor (owing to the SH groups) and stain clothing. Careful mixing is required to produce a homogeneous mix that is free of streaks. Both the working and setting times are relatively long. The curing reaction is accelerated by increased temperature or in the presence of moisture. The proportions of the base and catalyst should not be varied in order to adjust the curing rate.

The use of a chilled mixing slab increases the working time if the slab is not cooled so much that moisture forms on it. Addition of a drop of water to the mix decreases the working and setting times. The permanent

FIGURE 10–3 The four kinds of nonaqueous elastomeric impression materials. Two polysulfides at upper left and two condensation silicones at upper right. Two addition silicone products, lower left and center, and a polyether at lower right. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 138.)

TABLE 10–1. COMPARISON OF CERTAIN CHARACTERISTICS OF ELASTOMERIC DENTAL IMPRESSION MATERIALS*

	Polysulfide	Condensation Silicone	Polyether	Addition Silicone
Mixing	Fair to easy	Fair to easy	Easy	Easy
Flow	Variable	Good	Good	Good
Stack	Fair to good	Fair	Good	Fair to good
Elastic recovery	Fair	Very good	Very good	Excellent
Reproduction of detail	Excellent	Excellent	Excellent	Excellent
Odor and taste	Unpleasant	Acceptable	Acceptable	Acceptable
Cleanup	Difficult	Easy	Easy	Easy

*From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 149.

deformation after removal from undercut areas is relatively high. However, this property continues to improve after the material has reached an initial set. Thus, premature removal of a polysulfide impression from the mouth should be avoided. The stiffness is relatively low; hence, these materials are reasonably flexible. This facilitates removal of the impression from the mouth and separation of the cast from the impression. Nonetheless, the polysulfides are quite stiff in comparison with the hydrocolloids.

The tear resistance of polysulfide rubbers is good. However, considerable permanent deformation may occur during removal from the mouth if the impression material is removed from deeply undercut areas.

The curing reaction for the polysulfides is a condensation reaction (water is the by-product). This reaction leads to a moderate amount of curing shrinkage, which continues after the impression is removed from the mouth. Hence, the polysulfides are not sufficiently dimensionally stable to permit prolonged storage of the impression before pouring of the cast. Unset gypsum products tend to form a high contact angle on the surface of a polysulfide impression material. Thus, care must be used when the impression is poured to avoid trapping of air bubbles.

Condensation Silicone Rubber

Composition, Chemistry, and Properties

The silicone rubber base material is usually supplied as a paste in a metal tube (see Fig. 10–3). The reactor is generally in the form of a liquid and may be packaged in a bottle or in smaller metal tube. A puttylike viscosity is often available among the condensation silicone rubber materials, which are usually supplied in a jar, with a bottle containing the appropriate reaction liquid.

The base material is a silicon-based polymer called a *polysiloxane.* This liquid polymer is mixed with a powder silica (SiO_2) to form a paste. Polymerization occurs by a condensation reaction between the silicone base and a second silicon compound, an alkyl silicate. This reaction occurs in the presence of a catalyst, tin octoate. The alkyl silicate and tin octoate are combined to form the liquid component, which may be labeled "accelerator" or "catalyst." The by-product of the reaction is ethyl alcohol, which is rapidly lost by evaporation. This leads to a relatively high curing shrinkage and poor dimensional stability after polymerization.

The condensation silicone rubber impression materials are odor-free, clean, and relatively easy to mix. Proportioning is done by squeezing out a measured length of base material and adding the specified number of drops of liquid reactor. Varying the amount of reactor is the recommended way of adjusting the working and setting times, although increased temperature also accelerates curing. Working times tend to be rather short.

The permanent deformation of the condensation silicones is superior to that of the polysulfides (Table 10–1). However, the dimensional stability is inferior, and a condensation silicone impression should be poured as soon as possible after removal from the mouth. The contact angle of unset gypsum on a condensation silicone is even higher than on a polysulfide; thus, care must be taken in pouring the impression to avoid trapping of air.

Addition Polymerizing Silicone Rubber

Composition, Chemistry, and Properties

The addition polymerizing silicone impression materials represent the most recent development in the rubber elastomer category. Although they are based on silicone polymers, their chemistry and properties are quite different from those of the condensation silicones. They are packaged as a two-paste system in metal tubes (Fig. 10–3) or in plastic jars in the case of the putty material. They are commonly available in all four viscosity classes for a given product.

Curing occurs by the addition reaction of two different liquid silicone polymers, in the presence of a platinum salt catalyst, to form an elastic solid. No by-product is formed. Hence the curing shrinkage is small, and the dimensional stability is excellent. One of the two liquid silicone polymers is a polysiloxane terminated by a vinyl group, which is essential to an addition reaction. Thus, manufacturers frequently refer to the addition silicones as *poly(vinyl siloxane)* impression materials. As usual, powdered solids (silica) are added to the liquid polymers to form the two pastes or putties.

The addition silicones are odor-free, clean, and very easy to mix. The working and setting times are quite short. The curing reaction can be retarded by lowering the temperatures of the materials and of the mixing pad. Alternatively, a liquid retarder (supplied by the manufacturer) can be added to the mix. Base-catalyst ratios should *not* be altered from those recommended.

Permanent deformation and curing shrinkage are minimal. The dimensional stability is excellent, and most manufacturers claim that pouring can be delayed for up to seven days. The set material is quite stiff, and difficulty may be encountered in removing a full arch impression when significant undercuts are present.

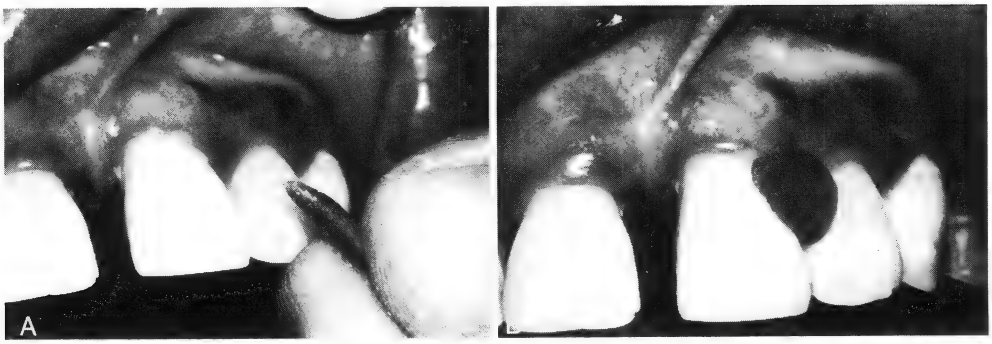

FIGURE 10–4

A, Soft utility wax formed into point.
B, Wax pressed into open embrasure to make removal of stiff impression material easier.

Wherever possible, open cervical embrasures should be blocked out with wax (Fig. 10–4). Care should be exercised during separation of the cast from the impression in order to avoid fracturing of the gypsum. The tear resistance is poor, but the material has low adherence to tooth structure and thus allows removal with little tearing. The material does not suffer appreciable plastic deformation before fracture. The wetting of the impression material by the mix of gypsum is similar to that discussed for the condensation silicone.

Polyether Rubber

Composition, Chemistry, and Properties

The base is a polyether that contains end aziridine rings. Activation occurs by a reaction consisting of an aromatic sulfonate ester. Both the base and reactor are supplied as a paste in collapsible tubes. Since the set material is quite stiff, a third component, called a body-modifier or thinner, is also available to reduce the stiffness. The body-modifier also reduces the viscosity of the unset material. This may be advantageous, since the polyethers are presently marketed in only a regular-viscosity consistency (see Fig. 10–3).

The polyethers are odor-free, clean, and easy to mix. They have very short working times, which can be extended by the addition of the body-modifier or by reducing the amount of reactor used in making a mix.

As can be seen in Table 10–1, the permanent deformation is comparable with that of the addition silicones. Since the polyether curing reaction produces no by-product, the curing shrinkage and dimensional stability are also quite good. However, the polyethers sorb water and swell. Thus, the impression must be stored in a dry environment until the cast is poured. The set polyether material does have a very high relative stiffness, which may pose clinical difficulties, although, as previously noted, the use of the body-modifier reduces the stiffness. Since the polyethers are somewhat hydrophilic, they form a low contact angle with gypsum and hence are easy to pour.

One additional caution should be noted. The polyether chemistry has been reported to create hypersensitivity in both patients and dental staff who are allergic to the material. If a known allergy exists, this material should be avoided.

THE IMPRESSION TRAY

A tray is needed to carry the impression material into the oral cavity and to confine it to the desired location as it hardens.

The tray must be rigid and dimensionally stable, provide space for the optimal thickness of impression material, promote good retention of the material to the tray, and possess a handle that allows a positive grasp of the tray. The tray must extend to include required areas while not impinging on other areas. It is also helpful if the tray has occlusal stops to allow proper orientation of the tray over the teeth and to prevent overseating.

Preformed metal and plastic trays are available that satisfy some of these requirements. Custom-made resin trays, when properly fabricated, meet all the desired characteristics and consequently are the best choice for all rubber impression materials. Reversible hydrocolloid requires metal trays through which water can be circulated for cooling and gelling of the material.

Fabricating a Custom Resin Impression Tray for Elastomeric Impression Materials

The tray is made on a diagnostic cast on which the working area is first covered with two layers of denture baseplate wax or beeswax to provide room for the impression material. A small portion of the wax is cut away in three occlusal locations, away from the teeth to be prepared (Fig. 10–5A, B). This procedure exposes the underlying tooth, so that resin can contact these areas and provide stops to orient the tray and prevent it from overseating and contacting the prepared teeth. The wax is then covered with aluminum or tin foil (Fig. 10–5C) to prevent wax contamination of the resin surface, since the adhesive used to hold the impression materials in a tray must contact a clean resin surface.

The tray should extend apically about 5 mm past the finish line of the abutment teeth (Fig. 10–5A). Tray coverage of other teeth need only be sufficient to record the form needed for esthetic and occlusal requirements. The tray extension should be marked by scribing a line

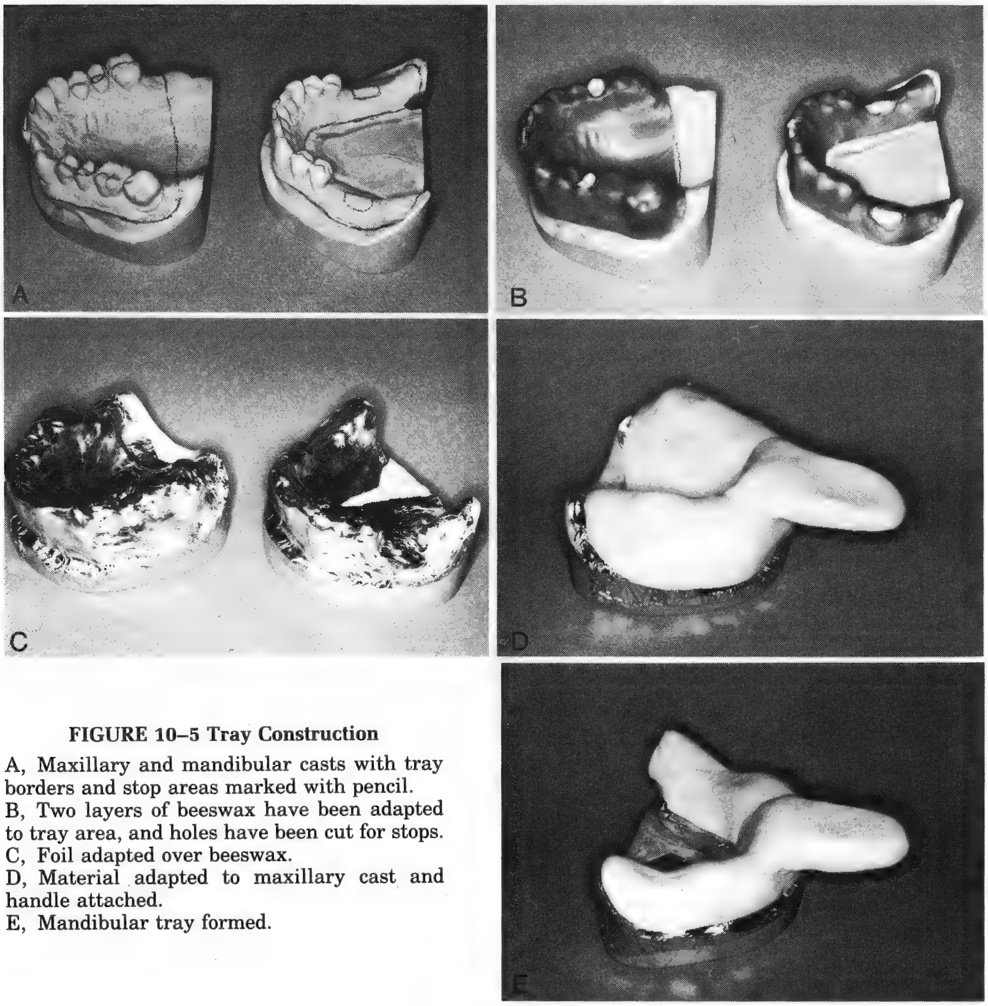

FIGURE 10–5 Tray Construction

A, Maxillary and mandibular casts with tray borders and stop areas marked with pencil.
B, Two layers of beeswax have been adapted to tray area, and holes have been cut for stops.
C, Foil adapted over beeswax.
D, Material adapted to maxillary cast and handle attached.
E, Mandibular tray formed.

in the foil. Overextension into bony undercuts is undesirable, since this makes removal of the impression from the mouth, and subsequently of the cast from the impression, much more difficult.

The tray resin is mixed as specified by the manufacturer and set aside until it develops a moldable consistency. When the resin is removed from the mixing container with a spatula, it should no longer exhibit the very stringy nature present shortly after mixing, nor should it stick to the fingers when handled.

The resin is formed into a shape appropriate to the area to be covered with a thickness of about 3.0 mm, placed over the foil, and hand molded until it covers the desired area (Fig. 10–5D, E). For maxillary trays, the palate can be covered, although this is not required. A sturdy handle should be formed and attached to the tray. The handle's shape can include mechanical undercuts to aid in grasping the tray. The handle should be attached at a location that allows the lip to drape naturally over the labial tray flange without being restricted by the handle.

It is best to fabricate the tray well in advance of its intended clinical use (such as the day before) to ensure complete resin polymerization.

When the resin has hardened completely, the foil and wax are peeled free from the tray (Fig. 10–6), and the appropriate adhesive is applied to the inner surface. The tray adhesive usually supplied for addition silicones has relatively poor holding qualities. Therefore, it is advisable to produce auxiliary retention when this material is to be used in undercut areas that cannot be blocked out. Perforation of the tray provides mechanical retention, which prevents pulling of the impression material from the tray when it is removed from the mouth. A PKT #1 waxing instrument can be pushed through the resin before it sets, or holes can be ground into the hardened tray with a number 8 round bur (Fig. 10–7).

To ensure good bonding between the impression material and tray, the adhesive must be completely dry when the impression material is placed into the tray. It is best to apply the adhesive at least 20 to 30 minutes prior to using the tray. A thin uniform layer of adhesive is best, since thick applications pool in depressions and are more resistant to complete drying (Fig. 10–8).

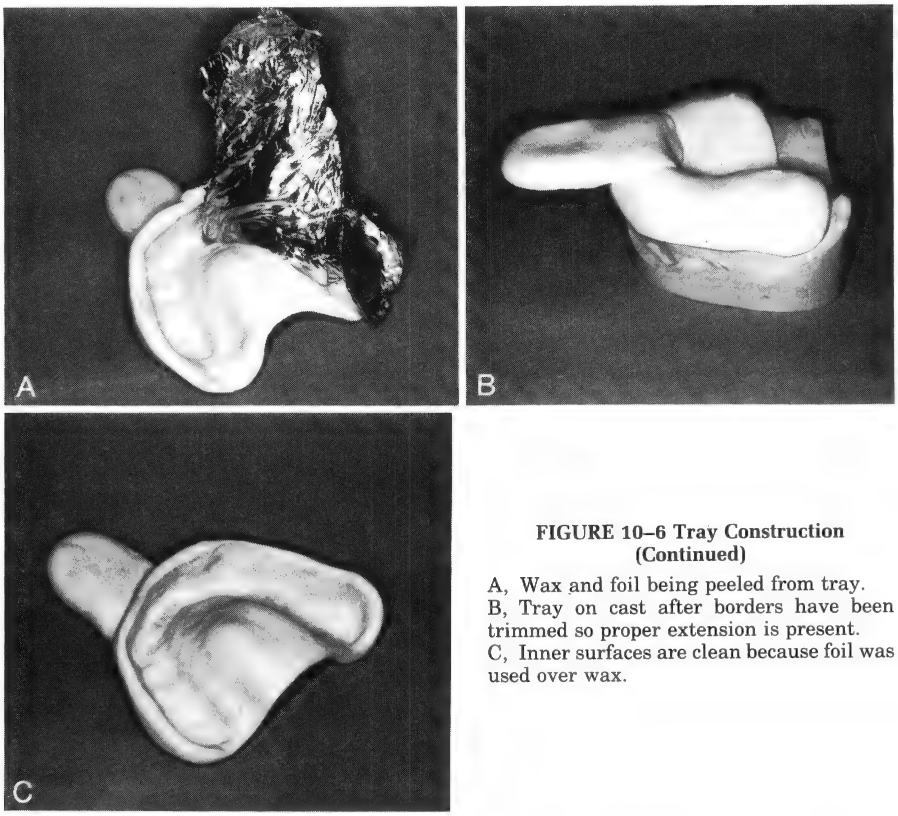

FIGURE 10–6 Tray Construction (Continued)

A, Wax and foil being peeled from tray.
B, Tray on cast after borders have been trimmed so proper extension is present.
C, Inner surfaces are clean because foil was used over wax.

PREPARING THE MOUTH FOR AN IMPRESSION

The prepared teeth, as well as the surrounding teeth or soft tissue whose shape is required for fabrication of the prosthesis, must be completely free of any surface debris and moisture. Cotton rolls and gauze should be placed to absorb moisture and prevent contamination of the cleaned areas.

When a preparation must be extended subgingivally, gingival displacement is required in order to evaluate the depth and uniformity of the finish line. Gingival displacement allows refinement and smoothing to be done without soft tissue laceration from rotary instruments. It also provides access to the finish line so that impression materials can be placed in a position that captures the shape of the finish line and the form of the unprepared tooth that is located cervical to the finish line.

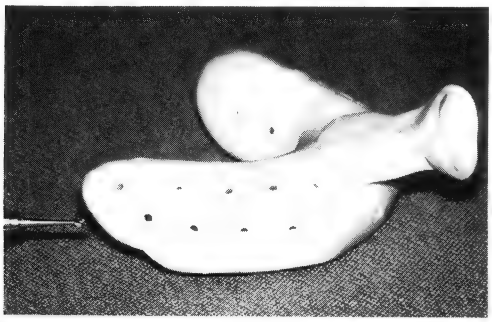

FIGURE 10–7 Resin tray perforated with number 8 round bur to provide additional retention.

Methods of Tissue Displacement

The gingival tissue can be retracted mechanically, chemically, or surgically. The best method of displacement is the one that causes the least amount of soft tissue trauma while providing good access to the finish line.

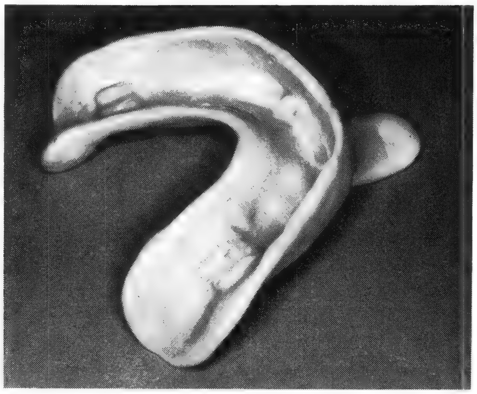

FIGURE 10–8 A thin uniform layer of adhesive has been applied.

FIGURE 10–9
A, Retraction cord being placed into gingival sulcus with a metal instrument.
B, Occlusal view of cord in place and tissue displaced.

Mechanical

The gingiva can be mechanically retracted by placing a small cord into the gingival sulcus and pushing back the soft tissue (Fig. 10–9). This procedure generally does not cause excessive trauma as long as short retraction times of 10 to 15 minutes are used. Times in excess of 20 minutes are much more likely to cause permanent soft tissue changes. Also, the cord should not be left in the sulcus during the entire preparation procedure, since this can promote gingival recession; it should only be inserted during the final placement and smoothing of the finish line.

Chemical

Chemicals are frequently used to enhance the retraction process and to control hemorrhage. Retraction cords are available that are impregnated with chemicals, or chemicals can be applied independently of the cord. Experience has shown that chemicals such as aluminum sulfate and aluminum chloride are safe when the time of usage does not exceed 15 to 20 minutes. Epinephrine is not considered acceptable for use on gingival tissue because of its systemic effect.

Surgical

When the finish line must be placed deep into the gingival crevice owing to caries, existing restorations, or other reasons, it may not be possible to refine the preparation or to obtain an impression without removing some gingival tissue.

Both electrosurgical procedures and periodontal surgery employing a scalpel have particular advantages and indications. The removal of small amounts of tissue (1 to 2 mm) is easily and effectively accomplished with electrosurgery without undue postoperative pain or healing problems. However, when large amounts of tissue must be removed, this is better accomplished through periodontal surgery. The end result is often superior, and there is less postoperative pain. Also, access to certain deep subgingival areas, particularly when the band of gingival tissue is narrow, may require apical repositioning of the tissue, which can only be accomplished by periodontal surgery.

Retraction Cord Technique

A retraction cord of the most appropriate size (that is, diameter) is selected by evaluating the tissue bulk to be retracted and its adaptation to the tooth. Thin firmly adapted tissue, such as that around many anterior teeth, should be retracted using the smallest available cord size. Medium-size cord is indicated when greater tissue bulk is encountered, such as with certain posterior teeth (Fig. 10–10). Retraction cord that is braided or woven does not separate when pushed into the sulcus with an instrument and is therefore much easier to use.

A small section of the selected size is cut to completely encircle the prepared tooth with about 5 mm of excess cord. A loop is formed and held with cotton pliers (Fig. 10–11A) so that it can be dipped as required into either

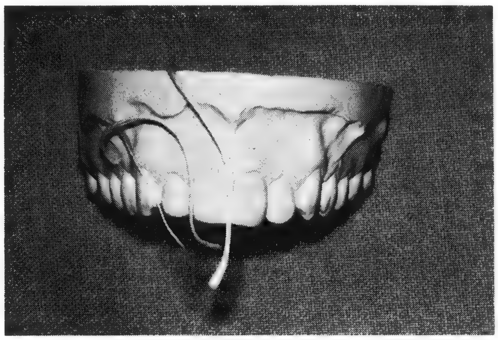

FIGURE 10–10 Three diameters of retraction cord placed on a diagnostic cast. The smallest diameter on the left is best used for thin firmly adapted tissues. The medium-size cord in the center can be used when greater tissue bulk is present or when greater retraction is necessary. The large-diameter cord on the right is too large and can produce excessive soft tissue trauma.

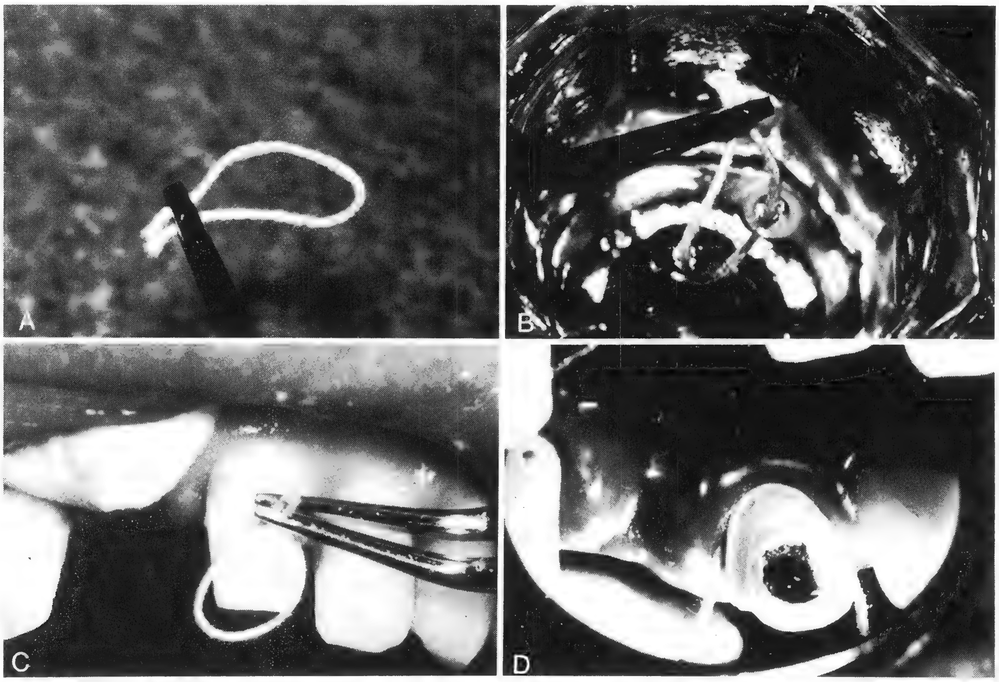

FIGURE 10–11

A, Loop of braided cord held with cotton pliers.
B, Cord being immersed in hemostatic solution in dappen dish.
C, Loop being placed over prepared maxillary central incisor.
D, Lingual view after cord has been inserted into sulcus to retract gingiva and expose finish line.

water or a hemostatic solution if hemorrhage is present (Fig. 10–11B). Moistening of the cord both softens and lubricates it, thus facilitating its placement into the sulcus without excessive force.

The cord is held around the tooth with the cotton pliers (Fig. 10–11C) and a metal instrument used to insert the cord into the sulcus (Fig. 10–11D). The insertion should begin interproximally, where more loose tissue is available, to allow the cord to slip easily into the sulcus. The retraction is continued until the cord is inserted into the sulcus around the entire circumference of the tooth (Fig. 10–12A). Excess cord length is removed with suture scissors so that only 2 to 3 mm of extra length remains. The excess is then packed into the sulcus over the other end of the cord.

Several types of thin bladed metal instruments are manufactured to place cord into the sulcus (Fig. 10–12B). Both smooth blades and ones with serrated edges to grip the cord are available. Also, the tip of a periodontal probe can be blunted to form an excellent instrument for packing thin cord around teeth with tightly adapted gingiva. The probe, as compared with the large bladed instruments, allows easier insertion of the cord into the sulcus, thereby reducing soft tissue trauma.

Following gingival retraction, the finish line location, depth, uniformity, and smoothness can be evaluated and refined as needed (Fig. 10–12C). Moving the finish line apically to the level of the retracted tissue (Fig. 10–12D) produces a subgingival finish line when the impression is obtained and the cord is removed (Fig. 10–12E).

Water spray is used to clean the retracted gingiva, the prepared teeth, and the surrounding area. Compressed air is then applied to remove excess moisture from the tooth surfaces and cord. Extensive and prolonged drying of the cord is not necessary and can actually dessicate it so that it adheres tenaciously to the tissue and causes tearing of the tissue and bleeding almost instantly upon removal.

Cotton rolls are placed in the facial vestibule and in the lingual vestibule on lower teeth to help control the flow of saliva. A saliva ejector may also be helpful. In cases of extreme salivation, and particularly when a lower impression is made, it may be necessary to administer an antisialogogue 1 hour before the impression is to be made.

The long end of the cord is now removed from the sulcus so it can be easily grasped when the impression material is ready to be placed around the tooth. Gauze squares are placed over the prepared teeth to absorb moisture entering the dried area, and the patient is allowed to close the jaws on the gauze and to relax the muscles while the impression material is readied.

Electrosurgical Tissue Displacement

Electrosurgical tissue removal is frequently used to enlarge the width of the gingival sulcus. The widened sulcus allows visual inspection and refinement of finish lines located deep in the sulcus, permits impression material to be deposited directly on the finish line, and

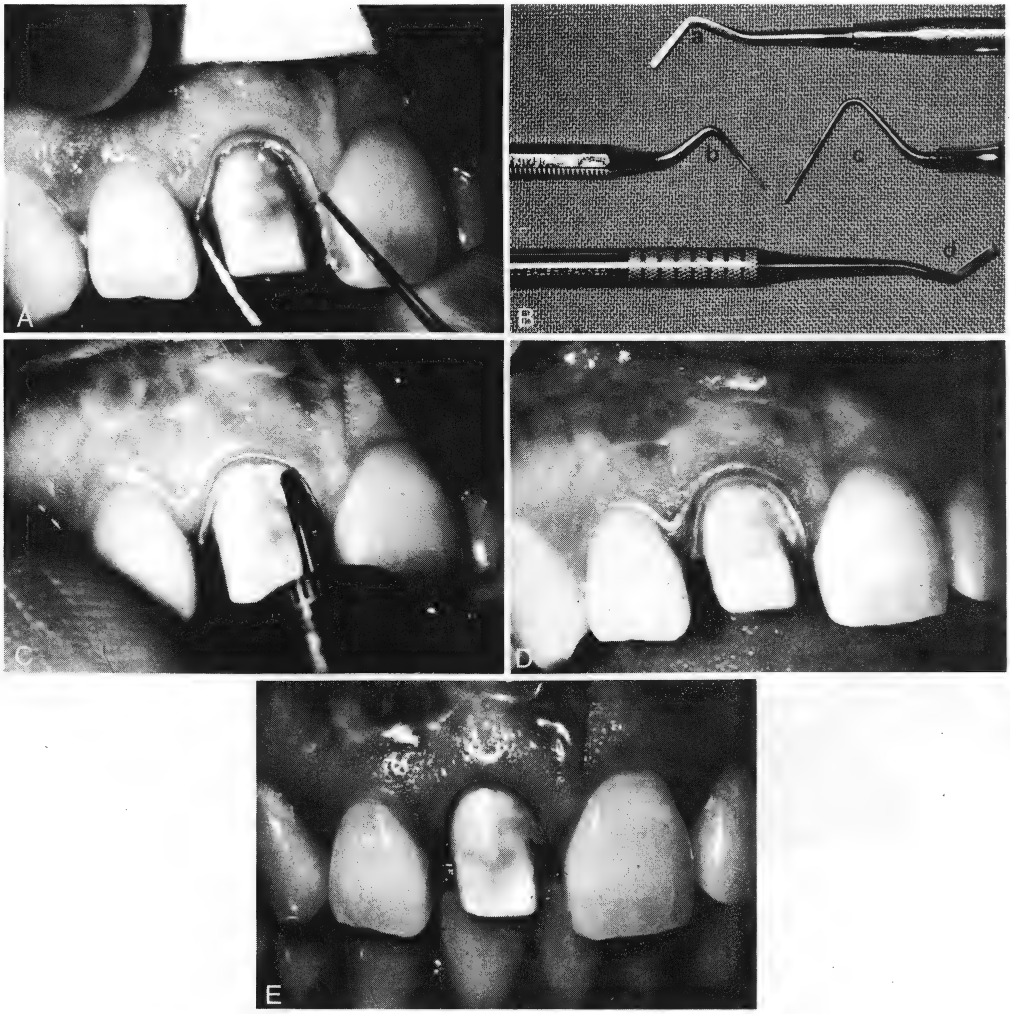

FIGURE 10–12

A, Cord being placed around maxillary central incisor so finish line of porcelain jacket crown preparation can be placed subgingivally and smoothed. Retraction was started on the proximal surface and has proceeded to the mesial surface.
B, Four instruments used for retraction: (a) S6 instrument, E.A. Beck and Co., Costa Mesa, CA 92627; (b) Guyer No. 7 instrument, American Dental Manufacturing Co., Missoula, MT 59806; (c) X1 periodontal probe, Marquis Dental Co., Aurora, CO 80011; (d) T. J. Balshi Packer, Premierlite Instrument, Premier Dental Manufacturing Co., Philadelphia, PA 19107.
C, Finish line being moved apically to level of retracted tissue and smoothed with rotary instrument.
D, Prepared tooth ready for impression with retraction cord present.
E, Retraction cord removed. Note shoulder is now located subgingivally.

allows the material to possess sufficient thickness so that it can be removed from the mouth without tearing. Only when absolutely necessary should the tissue be reduced in height, since this causes changes in tissue form that can affect the esthetic result in visible areas of the mouth.

Electrosurgical tissue removal should only be performed in the presence of healthy periodontal tissue; otherwise, significant changes in gingival form or height may occur on healing.

A complete discussion of electrosurgery is beyond the scope of this text, and information regarding different units, their operation, and preparation of the surgical area should be obtained from textbooks dealing specifically with this topic. Suffice it to say that the electrosurgery unit is readied for operation and the usual local anesthetic injection augmented by infiltration into the surgical area.

Tissue to be excised should neither be covered with fluid nor be completely dry. Removing excess fluid with compressed air while leaving the tissue moist provides the best environment for electrosurgery.

Widening the sulcus without removing excess tissue or reducing the height of the gingival crest is best accomplished by using the instrument tip that resembles an explorer. The tip is placed in the sulcus, the unit is

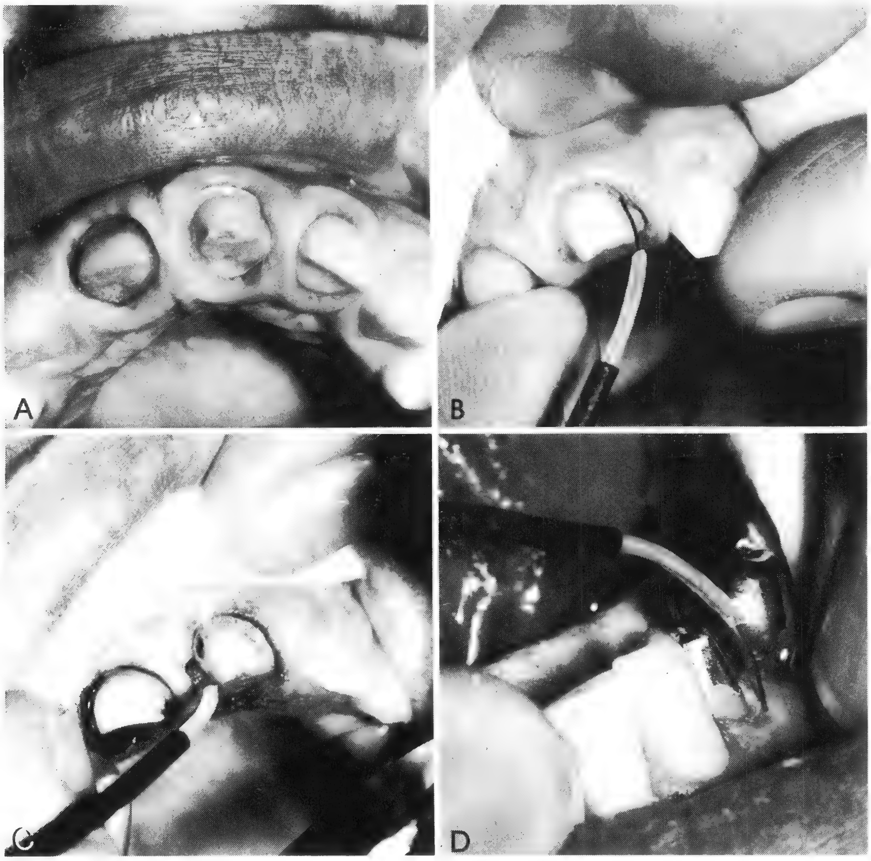

FIGURE 10–13 Electrosurgical Excision of Tissue

A, Prepared central incisors with subgingival finish lines. Obtaining an impression of the finish line requires widening of the gingival sulcus. The patient had been on Dilantin therapy.
B, Explorerlike tip being aligned with crevicular epithelium.
C, Tissue removed distally and lingually and surgery continuing on mesial surface.
D, Electrosurgery being used around a premolar. Note the angulation of the tip, which allows the sulcus to be widened without significant change in tissue height.

activated, and the tip is slowly and smoothly guided around the tooth and held parallel to the surface of the crevicular epithelium (Fig. 10–13). Ideally, the instrument tip should not be allowed to contact the tooth, and it must never touch bone.

The excised tissue is removed, and the surgical area is cleansed with 3 per cent hydrogen peroxide on a cotton pellet, followed by thorough irrigation with a water spray. Chemically impregnated cord is then placed in the sulcus to control hemorrhage as previously discussed. The mouth is dried, and the prepared teeth are isolated in preparation for insertion of the impression material.

TECHNICAL CONSIDERATIONS AND MANIPULATION OF ELASTOMERIC IMPRESSION MATERIALS

Since the manipulations of the four types of elastomeric materials are comparable, they are discussed together, with note made of any differences to be observed for each type.

As was pointed out earlier, manufacturers supply the materials in a number of consistencies. A very thin fluid mix is required if the material is to be injected over the prepared tooth by means of a syringe. A stiffer material is desirable for filling the tray, which is then placed into position over the syringe material that has previously been injected over the prepared tooth. Thus, the final impression is a combination of the two consistencies of the impression material. In yet another technique, a putty material is used in quite a different manner. It is employed to form a primary impression, which is then relined or "washed" with low-viscosity material to produce the final impression.

Shelf Life

The stability of a dental material when it is stored is referred to as the *shelf life*. Certain materials are sensitive in this regard, since ingredients may tend to settle out, temperature fluctuations may influence the reactivity, or undesirable chemical reactions may take place as the material ages. The end result is inferior handling characteristics and a loss in the required physical properties.

For this reason, the manufacturer usually labels the date on which the material was made. These labels are often part of the batch number, which is stamped on the box and the individual tubes of material. The user should ask the manufacturer's local distributor how the date of manufacture can be determined from the batch number. In the case of materials that are known to be susceptible to deterioration upon storage, it is advisable that the date of receipt be marked on every package when it arrives at the office.

The condensation silicone impression materials appear to be the most sensitive to prolonged storage. Most

of the addition silicones are now claimed to have a shelf life of at least 2 years. Regardless of the type, all rubber impression materials should be stored in a cool place, and refrigeration, if available, is desirable for the silicones. When a new package of material is received, it should be tested immediately for setting time. If it does not handle properly, it should be returned to the dealer.

TECHNIQUES

Two basic techniques are employed for making impressions with rubber base materials. In each technique, a syringe is used to inject small amounts of the very fluid material directly around the prepared teeth and any other areas in which precise detail is needed. An impression tray filled with the more viscous material is then seated over the syringe material. The two materials unite to form the impression.

The most commonly employed technique involves a one-step single-impression process and usually employs mixes of impression materials with two different viscosities. The lower-viscosity material is mixed first, loaded into the syringe, and injected into the mouth (Fig. 10–14A). While this is taking place, the assistant mixes the high-viscosity material and fills the impression tray (Fig. 10–14B). Alternately, the syringe and tray materials can be mixed simultaneously so that the operator and the assistant can cooperatively apply the lighter-body material around the prepared teeth and insert the tray. The assistant can retract the tongue or cheek as needed and hold the syringe or tray, allowing four hands to be simultaneously active. The loaded tray is then seated in the mouth and held motionless until the material sets and the impression can be removed from the mouth (Fig. 10–14C, D, E). In the case of impression materials that are supplied in only a single viscosity, a double mix would still be used in most cases, particularly with materials that have short working times. Other products are actually formulated for use with a single-

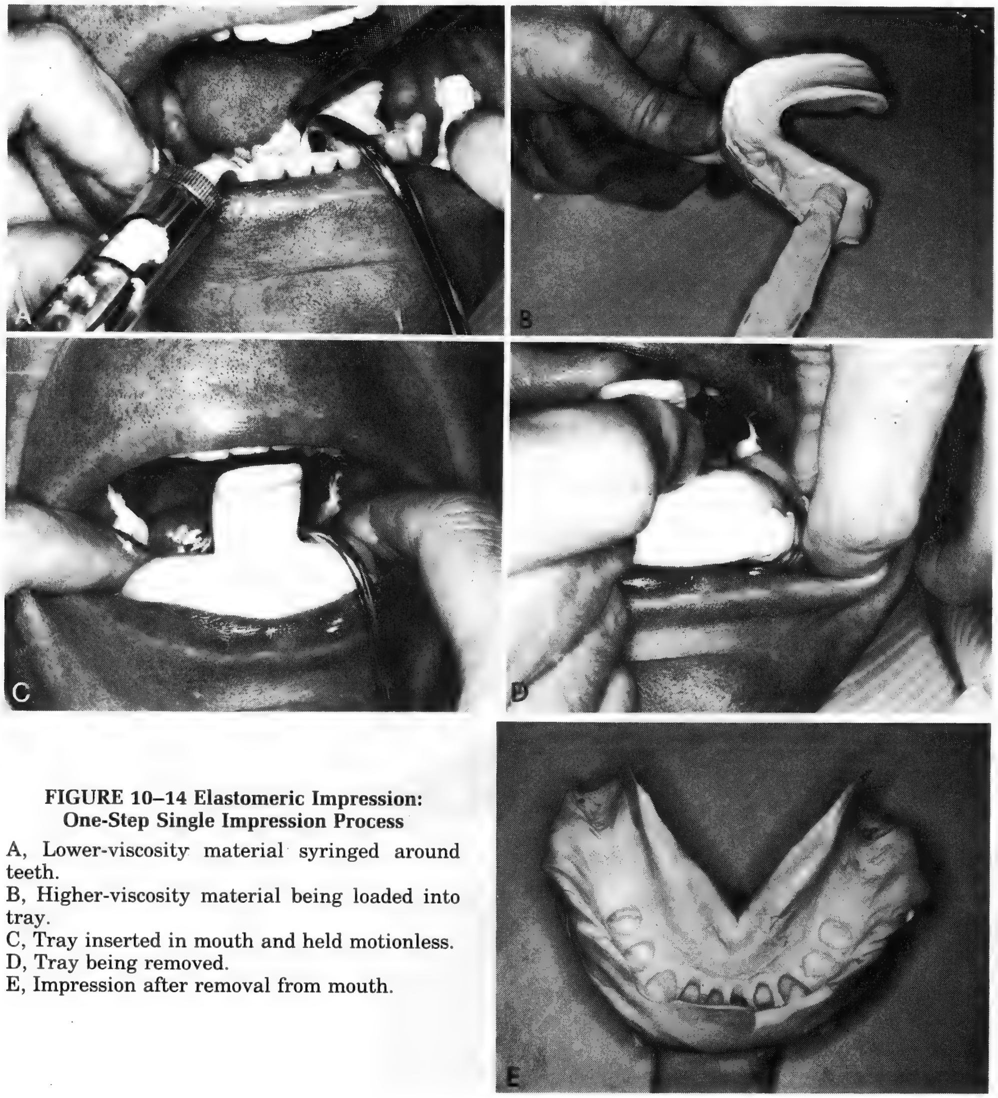

FIGURE 10–14 Elastomeric Impression: One-Step Single Impression Process

A, Lower-viscosity material syringed around teeth.
B, Higher-viscosity material being loaded into tray.
C, Tray inserted in mouth and held motionless.
D, Tray being removed.
E, Impression after removal from mouth.

mix technique. Advantage is taken of the increase in viscosity, which occurs after the material is mixed, in order to provide a heavier-body material for use in the tray.

The second basic technique employs a two-step impression process, which is often referred to as a *putty-wash* technique. A primary impression is taken in a stock impression tray, using a putty-viscosity type of material. This is not intended to provide a highly accurate impression, and in fact some relief space must be provided in the area of the prepared teeth. This space may be created by cutting away some of the set impression material or by placing a spacer over the teeth before the primary impression is taken. After the primary impression has been taken, a low-viscosity impression material of the same type is mixed and injected into the mouth by use of a syringe. Then the primary impression is reseated in the mouth over the "wash" material. The result is an impression with accuracy comparable with that resulting from the single impression technique.

Spatulation

Since the composition of the tube of base elastomer is balanced with that of the reactor or accelerator, the same matched tubes as originally supplied by the manufacturer should always be used. For this reason, it is not good practice to save a partially used tube of accelerator for use with a new tube of the polymer, or vice versa. If the lot numbers marked on the tubes are not identical, variation in consistencies or setting times of the mix should be anticipated.

With the polysulfide polymers, the proper lengths of the two pastes are squeezed onto the mixed pad (Figure 10–15). The reactor paste is first smoothed flat with a flexible yet stiff spatula so that both sides of the blade are covered. This procedure provides for greater ease in cleaning the spatula later, since the reactor paste is less adhesive than the base. The reactor paste is then incorporated into the base paste, and the mixture is spread over the mixing pad. This process is continued until the mixed paste is of uniform color, without streaks. A mix free of light and dark streaks should be attained in 1 minute or less, as illustrated in Figure 10–16.

The same procedure is followed in mixing the polyethers and addition silicones. However, the spatulation time should be limited to 45 seconds, since the mixed material will stiffen within 3 minutes or sooner.

If both the base and the accelerator are supplied in paste form, the mixing procedure with condensation silicone impression materials is the same as described for the polysulfide polymers. However, as noted previously, the reactor is usually in a liquid form, in which case the prescribed number of drops per unit length of paste is placed on or beside the rope of extruded paste (Figure 10–17). In either case, spatulation is continued until an even color is seen throughout the mass. It must be emphasized that regardless of the type of rubber—whether polysulfide, silicone, or polyether—curing will not be uniformly complete if the mixture is not homogeneous. In such a case a distorted impression is likely to result.

Application of Syringe and Tray Materials

Good access to the prepared teeth facilitates accurate placement of the lower-viscosity impression material. The patient should open the mouth wide and hold still while the cheek and tongue are retracted as necessary by the operator and assistant. The teeth and surrounding areas are then quickly redried with air as needed. While the assistant removes the retraction cord, the dentist follows immediately to inject the lighter-body material with the syringe (Fig. 10–18). This order of procedure allows the impression material to be deposited onto dry tooth structure before any fluid can seep over the clean surface. This is important because impression materials do not displace fluid. The syringe tip should follow and actually contact the finish line so that the material is placed where it needs to be located. The pressure of seating the tray or any other procedure such as blowing compressed air on the impression material cannot be relied on to force the material over all prepared surfaces. The plastic syringe tip can be heated and bent as needed so it can reach all areas of the prepared tooth (Fig. 10–19).

FIGURE 10–15 Equipment and materials for preparing a mix of polysulfide impression material. The dark material is the reactor paste, and the white is the base paste. (From Phillips, RW: Elements of Dental Materials for Dental Hygienists and Assistants. 4th ed. Philadelphia, W. B. Saunders Company, 1984, p. 122.)

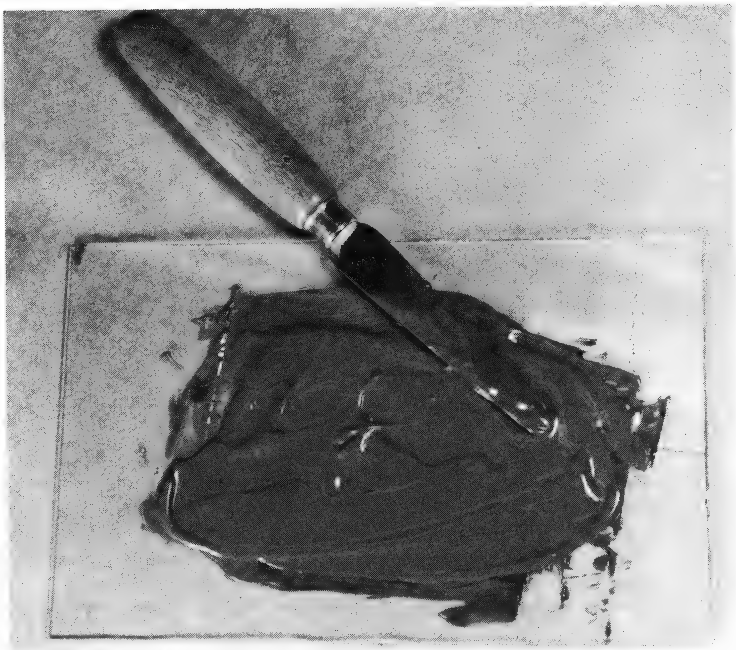

FIGURE 10–16 A proper mix of a polysulfide rubber impression material free of streaks. (From Phillips, RW: Elements of Dental Materials for Dental Hygienists and Assistants. 4th ed. Philadelphia, W. B. Saunders Company, 1984, p. 122.)

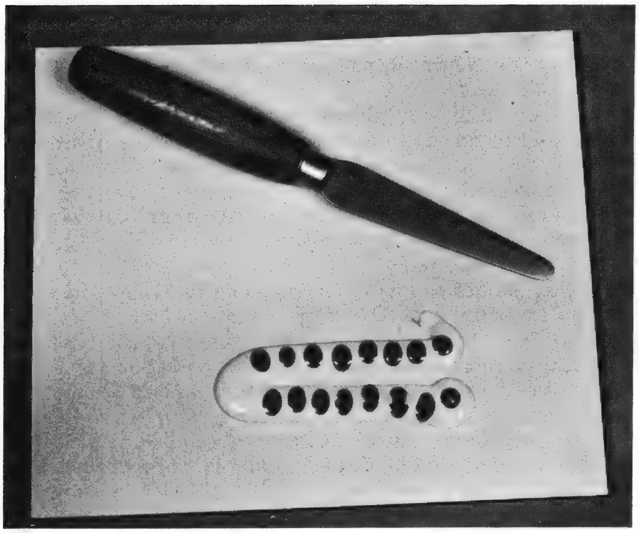

FIGURE 10–17 Mixing pad, spatula, and proportioned paste and liquid used for a silicone impression. (From Phillips, RW: Elements of Dental Materials for Dental Hygienists and Assistants. 4th ed. Philadelphia, W. B. Saunders Company, 1984, p. 123.)

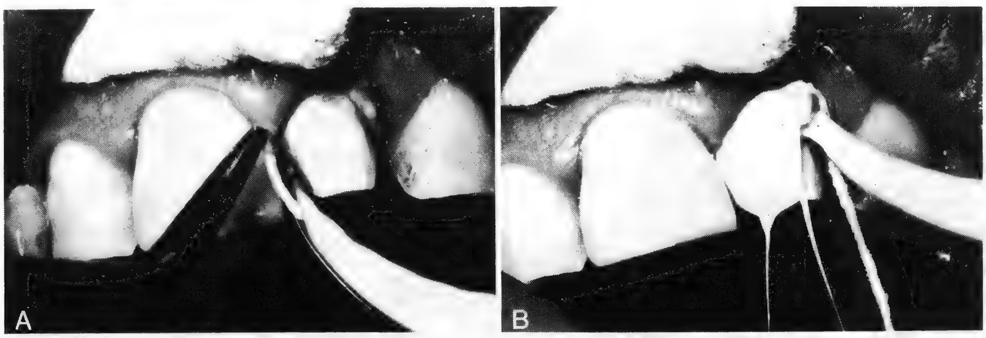

FIGURE 10–18

A, Cord being removed by assistant as dentist follows immediately behind, syringing light-body impression material.
B, Procedure continued across facial surface and into distal area.

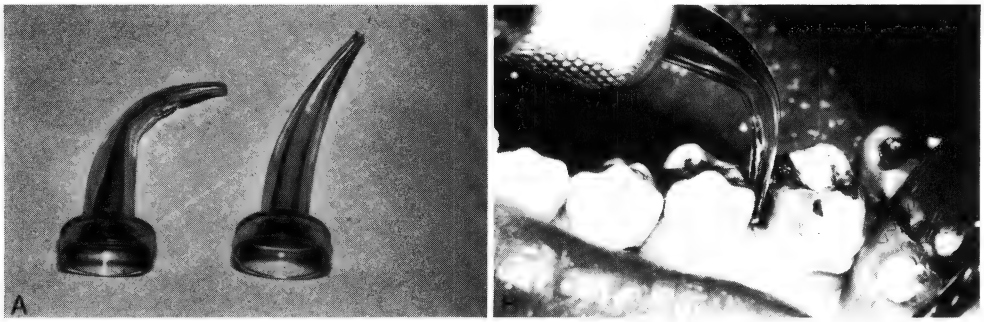

FIGURE 10–19

A, The tip on the left has been heated and bent to provide better access to the prepared tooth. The tip on the right possesses form as supplied by the manufacturer.
B, Bent tip providing better access to proximal finish line.

Syringing the clean and dry facial surfaces of any adjacent or contralateral teeth needed for the development of proper surface form in the final restoration allows the impression to more accurately record these areas. Likewise, syringing occluding tooth surfaces reduces air entrapment in the grooves and fossae and produces a cast that articulates more accurately. The loaded tray is then seated to allow the stops to orient the tray and limit its cervical movement.

Special Impressions

Impressions of tapered pinholes are best obtained by using a Lentulo Spiral instrument to carry and direct a low-viscosity elastomeric impression material to the bottom of each pinhole (Fig. 10–20A). The instrument should be rotated very slowly with a slight occlusocervical movement. The remainder of the prepared surfaces are then syringed as usual. As long as no undercuts have been inadvertently prepared in tapered pinholes, the set material can be pulled out of each pinhole and can accurately reproduce the internal details (Fig. 10–20B).

An impression of a parallel-walled pinhole must be obtained by placing a plastic pin into the pinhole. The pin should possess a head so it can be grasped by the impression material. The pin must also be slightly smaller than the pinhole so that the impression material is able to lift the pin out of the hole.

Impressions for the indirect fabrication of posts and cores are discussed in Chapter 27.

Tray Stabilization and Removal

The impression tray must be held passively until the material attains sufficient body so that it will not be distorted by tongue or cheek movements. The tray is left in the mouth for the full time recommended by the manufacturer.

Ideally, the tray should be removed in a direction parallel to the path of insertion. It should be lifted out of contact with all teeth simultaneously. This is best accomplished by grasping both buccal tray flanges, one with one hand and one with the other hand, and simultaneously exerting an occlusally directed force (Fig. 10–21). Some operators place small resin handles on the buccal flanges to facilitate tray removal. Removing the tray by using only the large handle, which is located anteriorly, causes the tray to tip away from the anterior teeth more rapidly than from the posterior teeth, so there is a greater possibility for tearing or distortion of the impression material. The anterior handle is designed primarily for tray insertion and, subsequently, for holding the tray while dental stone is poured into the impression to form a cast.

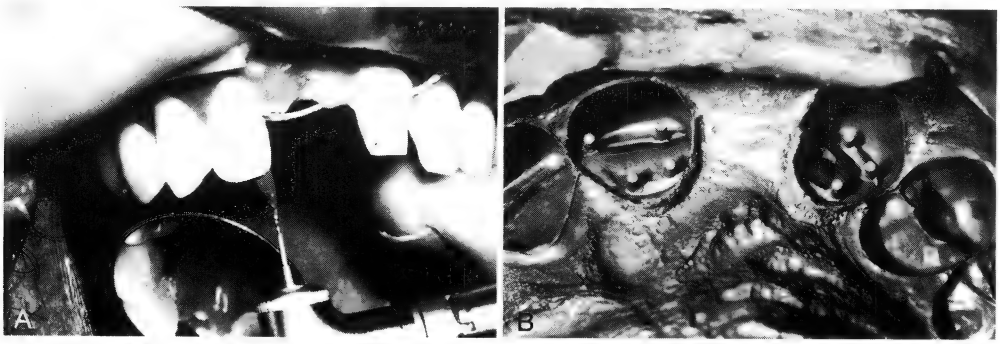

FIGURE 10–20 Impression of Pinholes

A, Lentulo Spiral Instrument being used to carry impression material to base of pinhole.
B, Impression from another patient with seven tapered pinholes.

FIGURE 10–21 Tray being removed by grasping both buccal flanges and pulling occlusally.

HYDROCOLLOID TECHNIQUE

Hydrocolloids are supplied as a gel in a sealed tube or clear plastic casing, which can be heated in water and softened. The material is then syringed around the teeth, and the tray is filled and inserted over the teeth. Cool water is circulated through the tray to produce gelation.

Gelation Temperature

The temperature at which the hydrocolloid impression material sets to a gel is important to the dentist. If the material gels at too high a temperature, injury may result to the oral tissues involved. If the surface of the sol gels when it contacts the tissues, a severe surface stress may develop. If the gelation temperature is too far below the oral temperature, it will be difficult or even impossible to chill the material to a temperature sufficiently low to obtain a firm gel adjacent to the oral tissues. Most modern hydrocolloid impression materials exhibit a gelation temperature between 36° C (97° F) and 42° C (108° F).

Gelation Time

Gelation of reversible hydrocolloid is, of course, a function of both temperature and time. The lower the ambient temperature, the more rapid is the gelation. Also, the longer the sol is held at a given temperature, the greater is the viscosity of the sol. The importance of leaving the tray in the mouth until the gelation has proceeded to a point at which the gel strength is sufficient to resist deformation or fracture is well known.

Preparation of Material

Proper equipment for preparing and storing the hydrocolloid is essential, and the dental office must be organized for this work. Various types of conditioners for preparation and storage of the hydrocolloid are available, such as the one shown in Figure 10–22.

The hydrocolloid is usually supplied in two forms.

FIGURE 10–22 A conditioner for the hydrocolloid technique. The various components are used for liquefying the material, for storage after boiling, and for conditioning the tray hydrocolloid. (Courtesy of Van R Dental Products, Inc.; from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 118.)

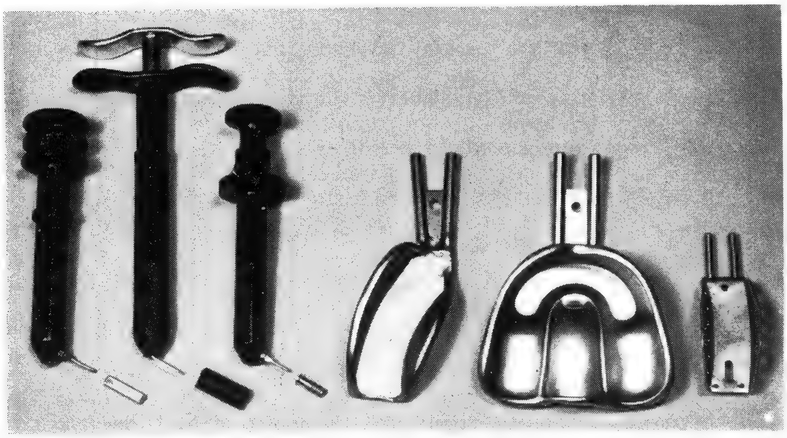

FIGURE 10–23 Armamentarium for use in obtaining impressions with hydrocolloid impression material. At the left, three types of syringes are shown that can be used for injection of the sol into prepared cavities. On the right are two water-cooled unperforated trays with overhanging rims for retention of the gel. At the extreme right is a sectional tray. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 118.)

Small sticks or cartridges are available for use in the syringes shown in Figure 10–23. By means of the syringe, the fluid material can be injected in and around the prepared teeth. Water-cooled trays (Fig. 10–23) are used to carry the hydrocolloid into the mouth to form the bulk of the impression.

The hydrocolloid that is used to fill the tray itself is liquefied in the metal or plastic tubes in which it is supplied. The only difference between the two types is a difference in color and a greater fluidity in the syringe material.

The first step is to reverse the hydrocolloid gel to the sol state. Boiling water is a convenient way of liquefying the material. A *minimum* of 10 minutes of boiling is essential, and there is no evidence that longer periods are harmful.

If the dental office is located in a city of high altitude, such as Denver, other methods must be used, since the boiling point of water is too low to liquefy the gel. A pressure cooker can be used, or an agent such as propylene glycol can be added to the water until a temperature of 100° C is attained.

Whenever the material is liquefied again after a previous use, it is more difficult to break down the agar brush-heap structure, so approximately 3 minutes should be added each time the material is liquefied.

After the material has been liquefied, it may be stored in the sol condition needed. Again, suitable equipment permits safe storage of the prepared material until it is needed. A storage temperature of 66° C (151° F) to 68° C (155° F) is usually ideal. Lower temperatures may result in some gelation and inaccurate reproduction of fine detail. Since temperatures required in the various steps of preparation of the hydrocolloid are critical, those in the different compartments of the conditioner should be checked each week.

Conditioning

The material that is used to fill the tray must be cooled or "tempered." The purpose of this *conditioning* is to increase the viscosity of the hydrocolloid so that it will not flow out of the tray and to reduce the temperature so that the material will not be uncomfortable to the patient. Therefore, the tray is filled and placed in the conditioning section of the equipment.

Since the rate of gelation is influenced by the temperature at which the hydrocolloid is held, various combinations of temperatures and times may be employed. A satisfactory one is to gel the material for approximately 10 minutes at a temperature of 46° C (115° F). The time may be varied for the particular batch or brand of hydrocolloid and for the fluidity preferred by the dentist. The lower the temperature, the shorter should be the storage time in the conditioning compartment. In any case, the loaded tray should never be stored in this bath for more than 15 minutes, since gelation may have proceeded too far.

Making the Impression

After the tray material has been conditioned, the prepared teeth are covered with hydrocolloid sol, using one of the syringes shown in Figure 10–23.

The sol, taken directly from the storage compartment, is first syringed at the base of the preparation. Next, the remainder of the prepared tooth is covered, as shown in Figure 10–24. The needle is held close to the tooth, beneath the surface of the ejected material, in order to prevent trapping of air bubbles.

When the entire technique is properly standardized, by the time the prepared teeth and adjoining teeth have been covered, the tray material is properly conditioned and is ready to be placed immediately in the mouth to form the bulk of the impression. The water-soaked outer layer of tray hydrocolloid is first blotted with a dry gauze sponge before it is placed in the mouth. Failure to do this may prevent a firm union between the tray material and the syringe hydrocolloid.

The tray is immediately brought into position and seated with passive pressure. The sol in the tooth bonds to the hydrocolloid in the tray to form a homogeneous impression.

Gelation is accomplished by circulating cool water, approximately 18° C to 21° C (64° F to 70° F), through the tray for not less than 5 minutes. *Care must be exercised to prevent any movement of the tray during the time the gel is forming*. After gelation, the impression is withdrawn in one piece. If properly done, the resulting impression (Fig. 10–25) is an accurate reproduction of the hard and soft materials.

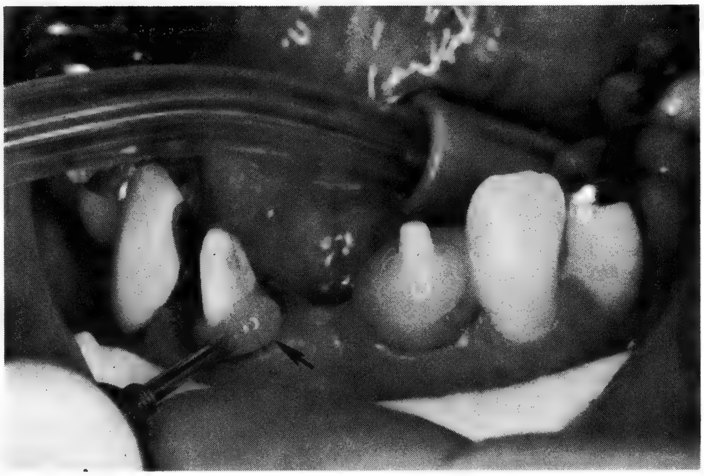

FIGURE 10–24 A hydrocolloid impression sol being injected (arrow) onto a full veneer tooth preparation. The impression material can be seen covering the preparation on the tooth at the right. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 119.)

Distortion During Gelation

Certain stresses are always introduced during gelation. The hydrocolloid materials contract initially after gelation. If the material is held rigidly by the retention in the impression tray, such a contraction of the material may be manifested by an expansion of the space or area surrounded by the impression. It is conceivable that portions of the impression near the tray may be enlarged.

In the case of hydrocolloid, the gelation begins adjacent to the cool tray and continues to the warmer oral tissues. Since the sol is a poor thermal conductor, rapid cooling may cause a concentration of stress near the tray when the gelation first takes place. Consequently, water at approximately 20° C (68° F) is more suitable for cooling the impression than is ice water, for example.

Distortion During Removal

The structure of the gel is such that a sudden force is always more successfully resisted without distortion or fracture than is a force that is applied slowly. Consequently, when the impression is removed, it is necessary to remove it suddenly, with a jerk, rather than to tease it out. Also, as noted previously, the removal is accomplished in a direction as nearly parallel as possible to the long axes of the teeth.

IMPRESSION EVALUATION

The impression must be thoroughly rinsed with water and dried with compressed air to allow accurate evaluation. However, excessive drying of hydrocolloid materials must be avoided. A small brush can be used with soapy water to remove any foreign material not eliminated by water alone. Then the impression is rerinsed and redried.

Under a bright light source, the surfaces representing the prepared teeth should be evaluated. All of the prepared surfaces, the entire finish line, and some unprepared tooth structure cervical to the finish line should be recorded in the impression. In addition, the occluding surfaces and the form of other teeth required for artic-

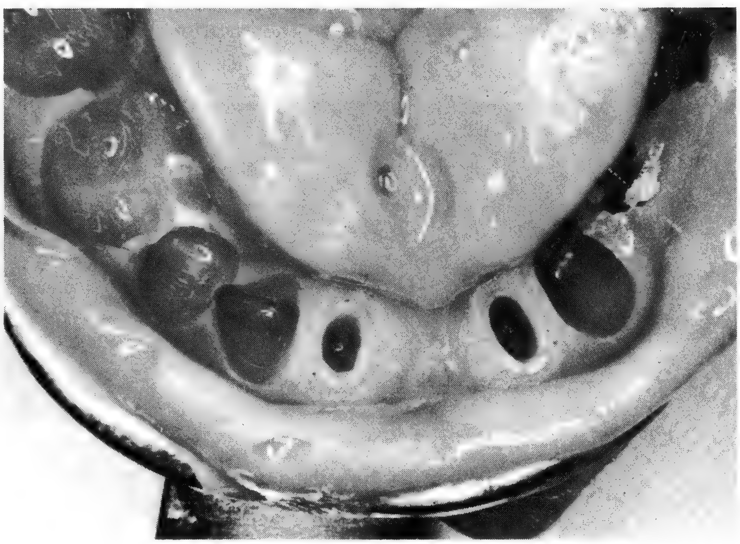

FIGURE 10–25 The final hydrocolloid impression taken of the preparations and teeth shown in Figure 10–24. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 120.)

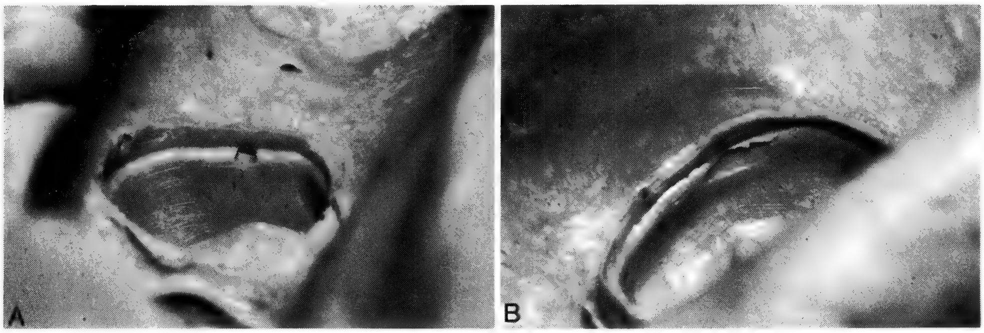

FIGURE 10–26
A, B, Voids located on finish line.

ulating the casts and shaping the prosthesis must be accurately reproduced. Failure to obtain all these details requires the making of a new impression.

The presence of voids on the finish line renders the impression unacceptable (Fig. 10–26). While not ideal, small pinpoint voids on axial or occlusal surfaces may be correctable by careful removal of the resulting nodule from the stone die after the impression has been poured. Large voids or folds are unacceptable.

With elastomeric impression materials, a shiny surface on the prepared teeth indicates that the material did not actually contact the tooth, and a new impression should be made. The shiny area is most often caused by fluid on the tooth surface, whereas a matte finish is developed on rubber materials when they contact a clean dry prepared tooth (Fig. 10–27).

CLINICAL RECORDS FOR MOUNTING WORKING CASTS

The proper settings for the angle of the eminentia, sideshift, and intercondylar distance should already have been determined from the previously mounted diagnostic casts, so records providing this information are not needed at this time. However, the working casts must now be mounted in the articulator so that the maxillary teeth are properly related to the rotational centers and the mandibular teeth accurately related to the maxillary teeth.

If a mandibular prosthesis is being fabricated and the previously mounted maxillary diagnostic cast is an accurate representation of current tooth form, it is not necessary to obtain a new facebow relationship. Instead, the mandibular working cast can be related to the previously mounted maxillary cast and mounted in the articulator. However, if the tooth form has changed as a result of such procedures as equilibration or the placement of new restorations, a new maxillary cast and facebow relationship should be obtained. Also, when maxillary teeth have been prepared, a new facebow recording should be made.

As discussed in Chapter 9, maxillary and mandibular casts can be interrelated by a centric relation registration or by maximal intercuspation of the teeth, depending on which is deemed more appropriate. Both techniques require accurate reproduction of occlusal surfaces in the impression.

Mounting by maximal intercuspation requires that a sufficient number of opposing teeth interdigitate properly to provide accurate three-dimensional orientation. When this situation does not exist, an interocclusal record must be obtained with the teeth in contact. If the remaining teeth are not distributed so that an interocclusal record can provide an accurate interrelationship, a stabilized baseplate and wax occlusion rim must be

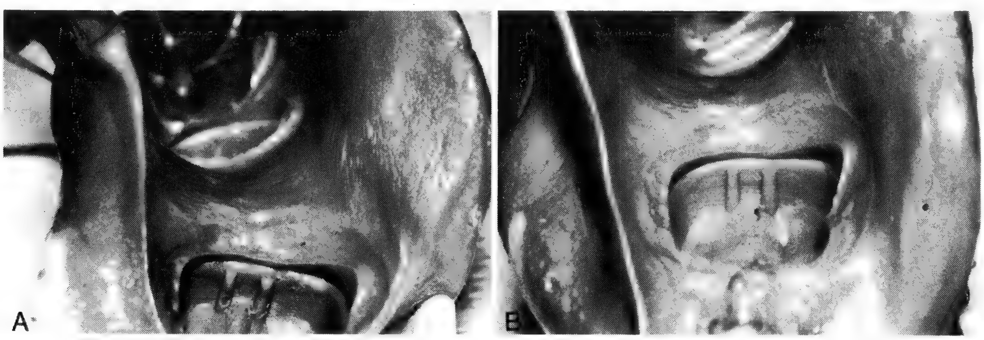

FIGURE 10–27
A, Inaccurate impression. Note the diffuse nature of grooves and the shiny appearance of material.
B, An accurate impression of the same prepared tooth. The grooves are sharp, and the surface possesses more of a matte finish.

fabricated. This cannot be accomplished at this time, since the baseplate must be made on the working cast. The impression must be poured and the baseplate fabricated, and the patient then returns for the interocclusal record.

If the casts are to be mounted in centric relation, a centric relation registration is obtained with the teeth sightly out of contact, as described in Chapter 9. A stabilized baseplate is also necessary when the remaining teeth are not well distributed.

The impression and interocclusal records are taken to the laboratory for use in the indirect fabrication of a prosthesis. Stone is poured into the impression to obtain dies and a working cast, and the interocclusal records are set aside for use in mounting the working casts in the articulator.

11

Dies and Working Casts

REQUIREMENTS FOR DIES AND WORKING CASTS

A die must be an accurate reproduction of the prepared tooth both in dimensions and surface details. It must represent all of the prepared surfaces, including the margins and a reasonable amount of the uncut apical portion of the tooth. Reproduction of the contour of the uncut portion is essential to the development of acceptable form in the wax pattern, which in turn is important to the maintenance of the health of the periodontal tissues and, in many instances, to the development of acceptable esthetics.

A die must be made of a material that is dense, hard, and capable of being used in the production of wax patterns and in the fitting and finishing of castings without undue risk of damage to its surface. Its form must permit accessibility to the margins for ease in adapting and contouring the marginal area of the wax pattern. Also, the die must be given a form that allows easy handling during waxing and other procedures. The last two requirements usually necessitate forming and trimming of the die so that it has a rootlike extension that serves as a handle (Fig. 11–1).

The working cast should exhibit all of the characteristics required for dies (except for good marginal access) but must meet additional requirements as well.

The adjacent and contralateral teeth must be reproduced in order to guide the creation of proper alignment, contours, and proximal contacts for the teeth to be restored or replaced. Copying of the edentulous ridge which a fixed prosthesis will contact is essential for satisfactory pontic fabrication. The occlusal and lingual surfaces of all teeth require accurate reproduction so that casts may be properly interdigitated on an articulator. Also, at least a few millimeters of the gingival tissues around the teeth to be restored should be reproduced. When enough teeth are missing to require the use of a stabilized base for mounting of the cast, it is essential that the involved edentulous areas be accurately represented on the cast. Each cast must have a base that allows firm attachment to an articulating instrument (Fig. 11–2).

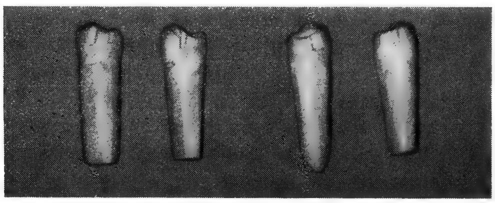

FIGURE 11–1 Trimmed stone dies with rootlike form.

FIGURE 11–2 Working cast for constructing crowns for the mandibular left first and second premolars.

The responsibility for producing dies and casts and their proper trimming usually lies with the dentist, since he has seen the final preparation, is best able to determine whether the die is an accurate reproduction of the preparation, and should know exactly where a margin lies on the die in a questionable situation. A technician cannot be expected to make such decisions routinely.

VARIATIONS IN DIE TECHNIQUES AND MATERIALS

The most commonly used die material is a Type IV gypsum, which is often called *die stone*. This material is relatively inexpensive, easy to use, and generally compatible with all impression materials. Its reproduction of detail and dimensional accuracy are considered to be adequate, the setting expansion being 0.1 per cent or less. The chief disadvantage of the gypsum die is its

susceptibility to abrasion during the carving of the wax pattern. Several means are used to increase the resistance to abrasion. However, these means may also increase the die dimensions, thus reducing accuracy.

The so-called *gypsum hardeners,* such as aqueous colloidal silica or soluble resin resolutions, can be used instead of water during mixing of the stone. Although this may not produce a significant increase in hardness, the resistance to abrasion is increased by approximately 100 per cent. A possible disadvantage is the slightly increased setting expansion. However, in most cases the increase is small and has little significance.

The abrasion resistance of the gypsum die can also be enhanced by treating the surface with a resin, such as epoxy, acrylic, styrene, or cyanoacrylate. The mixed but uncured resin is applied to the stone die, either in a concentrated form or diluted with an agent such as acetone. Dilution enhances penetration of the resin into the stone and reduces the tendency of the resin to increase the die dimensions. After the resin has been allowed to penetrate the stone, it polymerizes. Also, thermoplastic polymers, dissolved in volatile solvents to form a solution, may be used.

Such resin treatment can produce a moderate increase in strength and hardness of the gypsum, with the increase being directly proportional to the water/powder (W/P) ratio of the stone mix and, therefore, the porosity of the set gypsum. The increase in abrasion resistance is much more pronounced than is the increase in strength and hardness. The disadvantage of treating the set gypsum with such an agent is that the resin, if not handled correctly, can form an excessively thick surface layer.

Methods for Altering Die Dimensions

If the user desires a die stone that has less setting expansion than about 0.1 per cent, additional accelerator (potassium sulfate) and retarder (borax) can be added to the gauging water. By this method, a mean setting expansion of 0.01 per cent can be achieved when using some Type IV gypsum products.

At other times, a die slightly larger than the prepared tooth is desired, either to aid in compensating for the casting shrinkage of the alloy or to provide additional space between the tooth and the casting during cementation. To accomplish this, colloidal silica can be added to the gauging liquid.

Die spacers may also be used in conjunction with the stone die. The spacers are used to prevent the layer of cement from interfering with the complete seating of an otherwise precisely fitting casting. The most common die spacer is made by coating the gypsum die with a resin to within about 0.5 mm of the margin. Special proprietary paint-on liquids can be used, as well as model paint, colored nail polish, or thermoplastic polymers dissolved in volatile solvents.

Die Stone-Investment Combination

There is yet another technique that has been developed, one in which the die material and the investing medium have a comparable composition. A commercial gypsum-bonded material, called Divestment,* is mixed with a colloidal silica liquid. The die is made from this mix, and the wax pattern is constructed on it. Then the entire assembly (die and pattern) is invested in the Divestment to eliminate the possibility of distortion of the pattern upon removal from the die or during the setting of the investment.

Since Divestment is a gypsum-bound material, it is not recommended for high-fusing alloys, as are used in the metal-ceramic restoration. However, this is a highly accurate technique for use with conventional gold alloys, especially for extracoronal preparations.

Other Die Materials

Nongypsum die materials are also available, such as acrylic, polyester, and epoxy resins. These materials are limited in their compatibility with impression materials, which would ordinarily be nonaqueous elastomers rather than hydrocolloid. Compatibility is very specific and germane only to the particular brand rather than to chemical types of impression materials. Moreover, in the case of filled autopolymerizing acrylic resins, the curing contraction is excessive. Therefore, acrylic resin cannot be used when an accurate die is required. The same may be said for polyester resin materials. Various epoxy die materials do appear to be reliable in respect to dimensional change at polymerization, with this change being a linear contraction of about 0.1 to 0.2 per cent. Although epoxy dies are generally undersized in comparison with the prepared tooth, especially in the axial direction, they are said to be used successfully by some commercial dental laboratories.

In all fairness, it should be noted that in some cases the resin die is no more undersized than the stone die is oversized. However, this variation must be taken into consideration, since it may be necessary to adjust the investing and casting technique accordingly. A casting fabricated on the slightly undersized resin die fits on the tooth differently than one made on the slightly large stone die.

In the construction of a porcelain jacket crown, a platinum matrix is generally swaged on a die of the preparation. Since gypsum dies are readily damaged during swaging, a less brittle material, such as resin or metal, is preferred. The fabrication of silver-plated dies is discussed in Chapter 21.

All factors considered, the Type IV gypsums appear to be the most useful die materials for routine fixed prosthodontics.

HANDLING TYPE IV GYPSUM

Proportioning

Since high strength is desirable in dies and casts, as low a W/P ratio as possible should be used. However, decreasing the amount of water increases the viscosity of the mix, and care must be taken to ensure that the thick mixture flows into every detail when it is poured or vibrated into the impression.

Some dental stones (Type IV) can be used successfully with a W/P ratio as low as 0.20. It is important that the water and powder be measured. While water may be accurately gauged by volume, it is impossible to measure

*Whip-Mix Corporation, Louisville, KY 40217.

a powder accurately by volume because of the packing effect, which varies considerably with different commercial products of the same type. Consequently, the use of volume measurement for proportioning powders is unreliable, and weighing must be used.

If the maximal strength is desired, the W/P ratio should not be changed during mixing. If the proportions are achieved by guesswork, the addition of more powder to a mix that is judged to be too thin provides essentially two mixes of stone that will set at different times, and a weakened product always results. In the same manner, the addition of water to a too-thick mixture probably causes a disarrangement of crystalline growth and a lack of intercrystalline cohesion. The very fact that the mix was judged to be too thick may indicate that the setting reaction has started. As repeatedly stated, in order to obtain the maximal strength, the proportions of water and powder should be measured. Preweighed packages of stones are available.

Mixing

Hand Mixing

Hand mixing is accomplished in a flexible rubber or plastic bowl by using a stiff-bladed spatula. The mid-cross section of the interior of the bowl should preferably be parabolic in shape, so there will be no corners or other discontinuities in which the plaster or stone can collect and stagnate during the mixing procedure. The walls of the bowl should be smooth and resistant to abrasion. Any scratches or creases are likely to retain set plaster after the bowl has been washed. As a result, the setting time and other properties of subsequent mixes will be altered by the nuclei of crystallization unintentionally added.

The spatula should have a stiff blade. A flexible blade "drags" when it is forced through a thick mixture of stone and water, and as a result the mixing is seldom thorough. The end of the spatula should be rounded to conform to the shape of the mixing bowl, so that the surface of the bowl can be wiped readily by the blade of the spatula during mixing. The handle of the spatula should be of a design that can be readily grasped by the hand.

One great problem to be avoided during the mixing of a gypsum product with water is the incorporation of air. Air bubbles are unsightly, weaken the material, and produce surface inaccuracies.

The water should be placed in the mixing bowl, and the powder should be sifted into the water. When the powder sinks into the water without an agglomeration of the particles, less air is carried down. The mixing is completed when all of the mixture is smooth and homogeneous in texture. Further mixing is likely to break up the crystals of gypsum formed and thus weaken the final product. The time for hand mixing is approximately 1 to 2 minutes.

Mechanical Mixing

The use of a mechanical spatulator* to mix gypsum products offers considerable advantage. The rapidly moving blades of such a device tend to break up any air bubbles into fine voids, and the strength of plaster and stone is increased. Mechanical mixing for approximately 20 seconds under a vacuum almost completely eliminates air bubbles from the mix. One report noted that mechanical spatulation of Type IV stones did not produce a significant improvement in either the compressive or the tensile strength. However, another investigation found that mechanical spatulation, with or without vacuum, increased the strength of Type IV stones and that in only 10 seconds of mechanical mixing the strength was equal to that of stone prepared by a full minute of hand mixing. Possibly the differences reported may be attributed to the types of spatulators or brands of stone used. Certainly, mechanical spatulation does reduce the possibility of a void occurring in the die in some critical part of the tooth preparation.

*Combination Vac-U-Vestor and Power Mixer, Whip-Mix Corp., Louisville, KY 40217.

PRODUCING DIES AND WORKING CASTS

The Multiple Pour Intact Cast

This technique involves the use of a separate intact cast in addition to individual dies. It may be used with either one or two sets of dies. If two sets of dies are made, the dies from the first pour are reserved for use only in the final readaptation of the wax pattern to the marginal area and as an emergency back-up in case a second casting is needed after an unsatisfactory casting has been tried on the other die and marred it beyond use.

The use of individual dies together with an intact cast has several advantages: (1) the ease with which the wax pattern can be developed on the separate dies; (2) the accuracy with which proximal contacts can be developed; and (3) the accuracy with which a fixed prosthesis can be assembled on an intact cast. Also, an intact cast is generally easier to attach to an articulating instrument than one in which the dies are part of the working cast but removable from it.

The need to transfer the wax pattern between a die and a working cast is a disadvantage, particularly when there are inaccuracies in the working cast that cause pattern fracture. This problem is most apparent when the working cast is obtained from an impression that did not record all marginal areas and the die is made from a fully accurate impression. While this procedure can be acceptable, the defective areas must be completely trimmed from the working cast to allow complete and unimpeded seating of the wax pattern.

Nonaqueous elastomeric impression materials are best suited for this technique because a single impression can be poured to obtain individual dies and subsequently repoured to form an accurate working cast. To assure accuracy when using polysulfide or condensation silicone materials, it is important to complete all pours within 2 hours after removal from the mouth. The use of poly (vinyl siloxane) impression materials, with their long-term dimensional accuracy, has made the multiple pour technique more attractive, since the procedure may be completed over a longer time period (days if necessary). Obviously, the multiple pour technique cannot be

employed with hydrocolloid impression materials unless more than one impression is obtained, since removal of the first pour ruins the impression.

The Removable Die Cast

The use of removable dies requires that the impression be poured only once, although the single pour may be made in two stages, depending on the method chosen. As would be expected, this method is popular among those who use hydrocolloid impression materials, since only one impression is required. Basically, this method allows the die for a prepared tooth to be removed from the cast for certain fabrication procedures, such as initial wax application, and then to be returned to the working cast in an acceptably accurate manner for completion of the wax pattern form and development of correct occlusal relationships.

The advantages of this technique are that it is suited to any impression material, and once the initial pour is made, the rest of the procedure may be completed as time permits. However, slight positional variations occur when the dies are reseated in the working cast, and these discrepancies can prevent accurate prosthesis assembly from the working cast. The magnitude of the discrepancy in abutment tooth alignment varies with the type of removable die working cast used and the accuracy with which it is fabricated. Also, the presence of wax particles or other debris may interfere with the complete repositioning of the die, thus creating an inaccuracy in the occlusion or an ill-fitting prosthesis.

There are several approaches to the production of casts with removable dies. One involves the use of a multiple-piece interlocking plastic form into which a working cast is embedded with dental stone. When the form is disassembled, the cast can be removed and the dies separated by cutting them out with a disc or saw. Then the stone parts can be replaced and held securely in position by reassembling the plastic form.

Another approach is the use of tapered metal dowel pins, which are embedded in the dies and fitted into the base of the working cast to allow the dies to be removed from the working cast and repositioned as needed.

There are several other means of indexing removable dies to the working cast; however, only the two described here are included in the sections that follow.

PREPARING AN IMPRESSION FOR POURING

An impression must be clean and free of all surface debris and contaminants before stone can be poured into it. The presence of saliva or blood interferes with the proper setting of gypsum products and causes the stone surface to be soft, chalky, and inaccurate. In addition, all rubber impressions should be completely dry when poured. However, while the surface of a hydrocolloid impression must be free of contamination by debris, blood, or saliva, the material must not be dehydrated by excessive use of compressed air. Drying inevitably causes dimensional change. While it is necessary to remove the bulk layer of moisture, the surface of the hydrocolloid impression should still glisten.

MULTIPLE POUR INTACT CAST TECHNIQUE

Pouring the Impression

The die stone and its liquid are measured and mixed as previously described (Fig. 11–3). When properly proportioned and mixed, the stone should have a consistency that flows readily but that allows it to stay in place when not disturbed. A small amount of properly mixed die stone is picked up with a small stiff brush or a small metal instrument and placed on the inside edge of the impression of one of the tooth preparations and vibrated to the bottom of the impression using a mechanical vibrator. The stone may be introduced directly into the bottom of the tooth impression if the preparation is big enough to allow this without the entrapment of an air bubble (Fig. 11–4A). Care is taken to observe the flow of the stone in order to determine that no air bubbles are trapped in the fine detail of the impression as the stone flows into it. Should this happen, the brush may be used to tease out the bubble, or the impression may be partially inverted on the vibrator to allow the stone to flow out; then the stone can be reintroduced into the impression of the prepared tooth. The addition of small increments of stone is continued until the impression of the preparation is filled with a slight excess of material. The other prepared teeth are poured

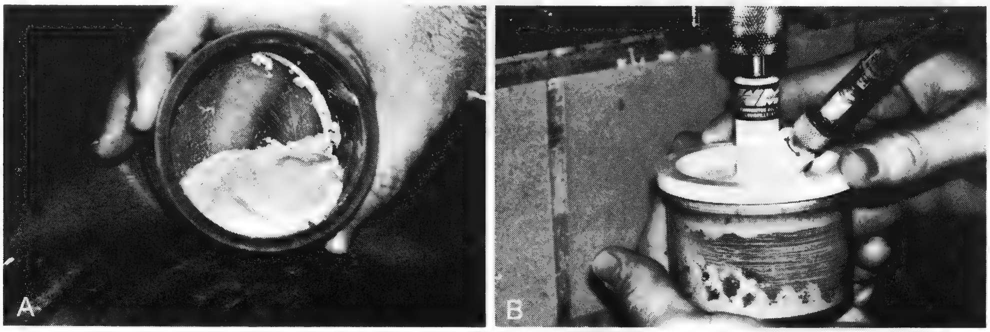

FIGURE 11–3 Mixing Stone for Dies

A, Stone mixture after it has been hand spatulated.
B, Vacuum spatulation of the mixture.

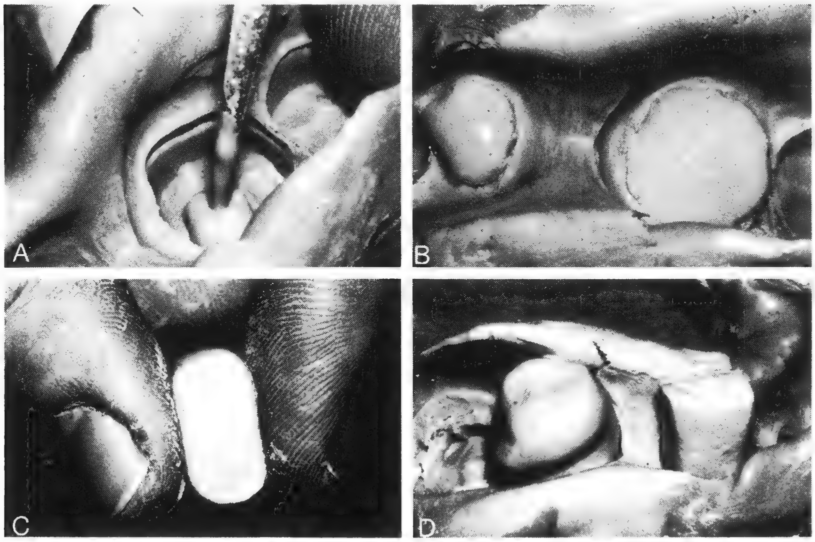

FIGURE 11–4 Pouring Dies

A, Brush being used to place mixed die stone onto the occlusal surface of the impression.
B, Impressions of the prepared teeth filled with stone.
C, Blotted stone formed into a root.
D, Stone roots in place. Molar root not sufficiently blotted.

individually in a similar fashion (Fig. 11–4B). When all impressions have been filled, an amount of mixed stone sufficient to form a "root" for the die is picked up and shaped with the fingers. Usually it is necessary to reduce the water content somewhat by blotting it with a paper towel. This produces a moldable consistency, which allows the material to be positioned on the stone already in the impression and to remain in place until it has set (Fig. 11–4C, D). The procedure is repeated for each of the prepared teeth represented in the impression.

After about 30 minutes the stone is set enough to allow safe removal of the dies (Fig. 11–5A). However, maximal physical properties are not yet achieved, and the dies should be handled very carefully to avoid damage. If a second set of dies is to be obtained, these procedures are repeated.

Depending on the number of sets of dies needed, either a second or third pour is made to obtain a working cast (Fig. 11–6). The stone is mixed and placed in the impression as before, starting with the prepared teeth and then continuing to include all teeth and the remainder of the impression.

Once the impression is filled, a base may be formed by inverting the poured impression onto an appropriate amount of stone placed on a smooth clean surface, such as a glass plate or a ceramic wall tile. Some individuals think that a certain amount of accuracy may be sacrificed by inverting the impression and prefer to form the base as a second procedure, following the initial set of the stone. In any case, the base should be sufficiently thick to give strength to the cast and to allow easy attachment to an articulator. In most cases, a base 10 to 15 mm thick, in addition to the stone contained in the impression, suffices and does not interfere with proper positioning in the articulator. Rubber forms are available to aid in producing bases for working casts. They may be filled with stone, and the just-poured impression can be inverted and put in place, or they

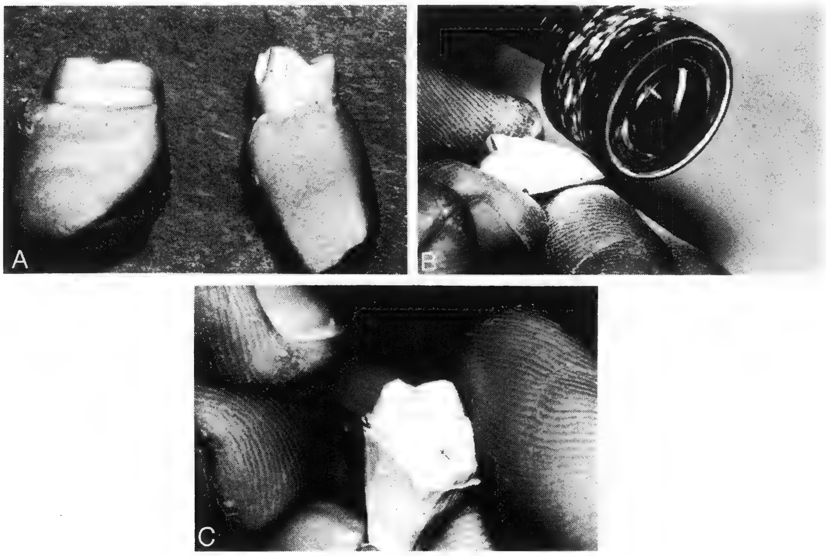

FIGURE 11–5 Trimming Dies

A, Untrimmed dies separated from impression.
B, Trimming root of die with lathe and arbor band.
C, Forming the cervical area of the die by carving away excess stone with number 11 scalpel blade.

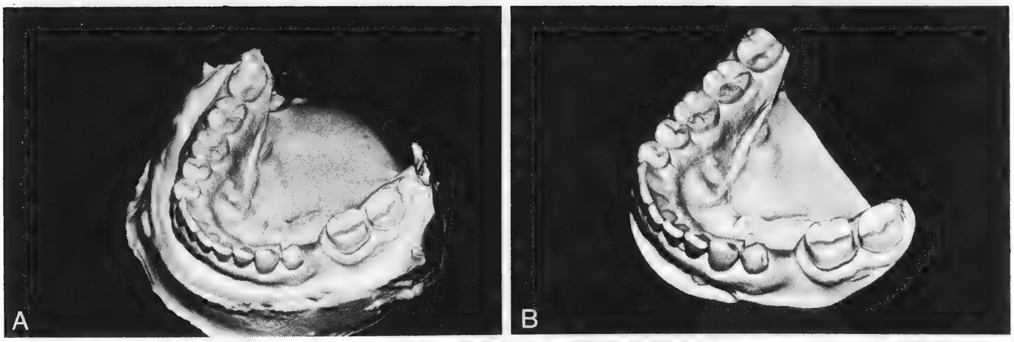

FIGURE 11–6 Working Cast
A, Set cast before trimming.
B, Base trimmed with model trimmer.

may be used to form a base after the initial pour has been allowed to set.

Trimming Dies and Casts

Dies

Ideally, the greatest dimension of a die should be at the cervical finishing line. If a die is trimmed to achieve this form, it is easy to approach the finishing line with a waxing instrument held at the optimal angle for production of a contour that is compatible with the remaining uncut tooth structure. Also, the finish line can be approached from either an occlusal or a cervical direction.

The first step in trimming is to separate adjacent dies from each other, or dies from adjacent teeth if they were inadvertently included in the die pour. This may be done with a disc used in a dental lathe or with a saw. Next, the size of the base of the die is reduced with abrasive wheels or arbor bands used in a lathe (see Fig. 11–5B). This step should approach the finishing line or the cervical line to within 0.5 mm and should produce a smooth taper apically.

The final step is the careful trimming of the excess stone below the cervical finishing line. A number 11 scalpel blade is excellent for this purpose (Fig. 11–5C). The use of magnification may also be helpful for this procedure and is recommended. In any case, extreme care must be taken not to mar the margin. After marginal trimming, slight reshaping of the stem form may be needed.

Generally, the procedures involved in trimming dies are more easily done if the stone has been given a chance to dry at least partially. Wet stone tends to load up on a grinding instrument and impedes its function. It is best to delay trimming the dies at least overnight and preferably for 24 hours to allow for more complete development of the desired physical properties of the stone.

The Working Cast

The cast should be trimmed wet on a model trimmer so that its base allows proper positioning in the articulator and so that there is free access to the working area. Care should be taken not to overtrim and damage the teeth or other critical areas of the cast. The presence of excess water while the model trimmer is in use should be avoided, since stone is soluble and the surface of the cast can be eroded. A base thickness of 10 to 15 mm is usually satisfactory (Fig. 11–6).

REMOVABLE DIE TECHNIQUES

The Dowel Pin System

Manufactured tapered and keyed metal dowel pins may be used to make dies removable from and replaceable on a working cast. Such pins are usually made from brass, tapered to allow removal, and flat on one side to provide for accurate reseating (Fig. 11–7A).

Pouring the Impression

Initially the impression is poured in die stone to a level that includes at least the coronal portion of all of the teeth and 5.0 to 8.0 mm more in the areas including the prepared teeth. The additional thickness here is to allow enough length for adequate trimming and shaping of the cervical portions of the dies. Before the stone sets, the dowel pins are placed in each of the prepared tooth areas and stabilized in position (Fig. 11–7B, C). Special dowel holders are available for this purpose; alternatively, common straight pins can be inserted into the impression and used to support the dowel pins by attaching them to the straight pins with sticky wax. Wire loop connectors, which can be made from the bent portions of paper clips, are positioned in the stone at strategic intervals. At least one loop must be placed in each edentulous area between dies and in each section containing intact teeth. The loops function to make certain that the initial portion of the cast remains attached to additional stone, which will be added later.

When the stone has set, a separator such as petroleum jelly is applied to each die area, and the base of the cast is poured with a new mix of die stone (Fig. 11–7D). A small ball of utility wax, about 5.0 mm in diameter, is placed on the tip of each pin as an aid to finding the pin tip in the set cast. This also produces a void in the cast, which permits access to the pin tip for purposes of removal.

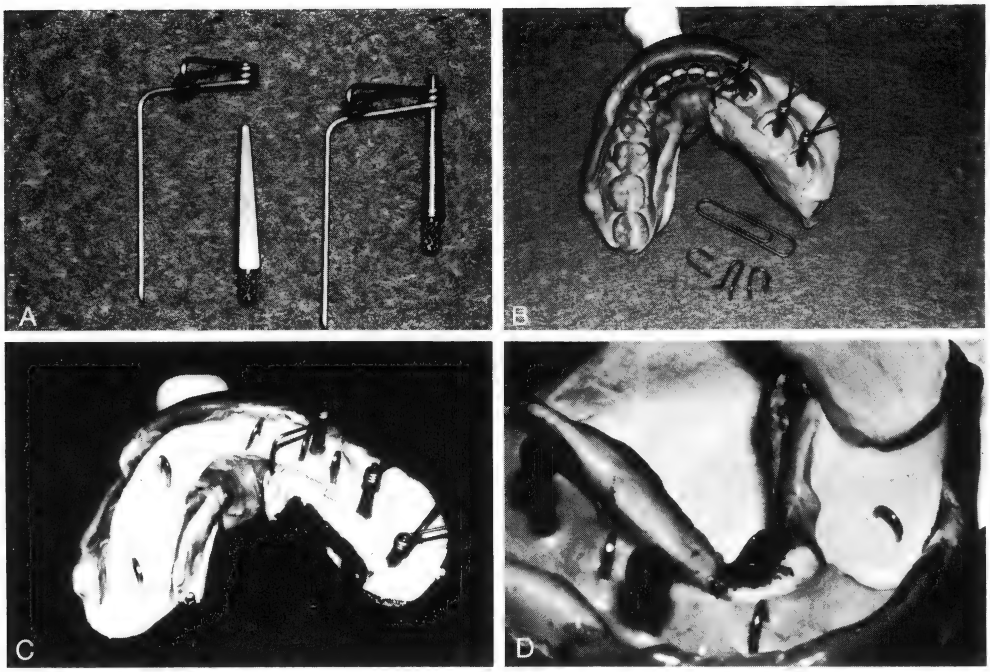

FIGURE 11–7 Pouring Impression Using Dowel Pins

A, Tapered dowel pins together with spring holders used to maintain pins in position while stone sets.
B, For the purpose of demonstration, the dowel pins are temporarily located using the spring holders. They are normally placed after pouring but before the stone begins to set. Note the modified paper clips to be used to lock the second pour to the first.
C, First stone pour completed with pins and paper clips in place.
D, Initiation of second pour to form base for cast. Note the round bead of utility wax, which has been placed over the ends of the dowel pins.

Preparing the Cast and Dies

After the stone sets, the cast is removed from the impression and trimmed as necessary. The base is reduced to expose the wax on the end of each dowel pin, and the dies are separated and trimmed as described (Fig. 11–8). As the cast is attached to an articulator, access to the dowel pin tips must be maintained.

The Di-Lok System

The Di-Lok Tray* is a device that is used to allow dies to be removed and returned to the working cast with accuracy. It is an interlocking device that holds all of the parts of a sectioned working cast. While the Di-Lok system maintains adequate tooth relationships, its bulk makes it rather cumbersome to mount on an articulator, particularly one employing a facebow transfer.

Pouring the Impression and Adapting Cast to Tray

The cast for use with this device is first poured in die stone with a base that is 10 to 12 mm thick and has a horseshoe shape with no stone in the tongue or palatal spaces. After the stone has set, the base is trimmed to produce a flat inferior surface and facial and lingual surfaces that converge apically. The facial and lingual reduction should be to within 1 to 3 mm of the gingival lines of the teeth. This size should allow the trimmed cast to fit loosely into the plastic tray. Once the cast has been fitted to the tray, horizontal retentive grooves are cut into the vertical surfaces of the cast (Fig. 11–9A). These grooves are made with a cutting disc and serve to make certain that the stone pour used to adapt the cast to the tray does not separate during use.

The assembled tray is about two-thirds filled with a mix of regular dental stone and the cast is carefully settled into it (Fig. 11–9B). Additional mixed stone may be applied or stone may be removed to achieve a level approximately even with the trimmed portion of the cast and the top surface of the tray.

Preparing the Cast and Dies

When the investing stone has set, the tray is disassembled, and the cast is removed by tapping the anterior part of the plastic tray on the bench top (Fig. 11–9C). The dies are then separated, using either a fine hand saw or a thin disc in a dental lathe (Fig. 11–9D). After sectioning, the cervical portions of the dies are trimmed as described earlier (Fig. 11–9E). When all dies have been trimmed, all stone parts are replaced on the center portion of the assembly (Fig. 11–9F) and locked into position by replacing the outer rim of the tray.

MOUNTING THE CASTS

The casts are mounted in the articulator using a facebow recording and an interocclusal record (see Chap. 9).

*Lactona Corp., Morris Plains, NJ, 07950.

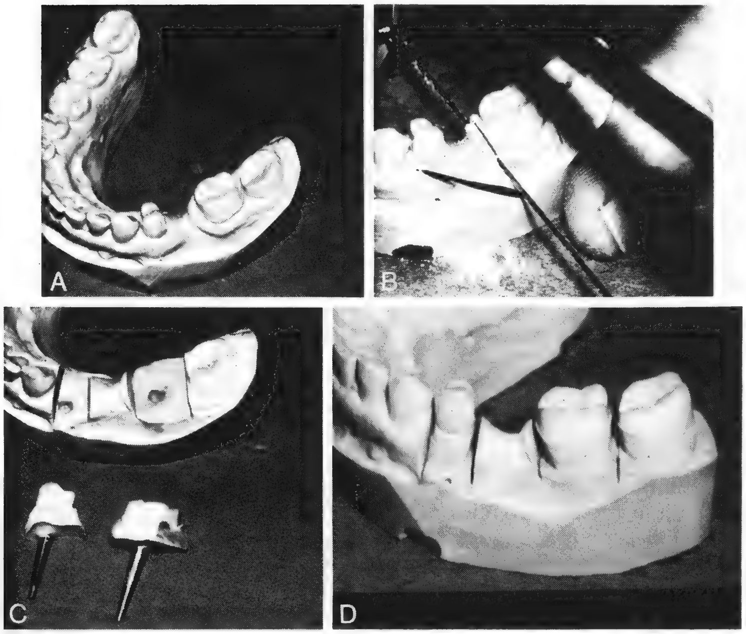

FIGURE 11–8 Sectioning the Cast

A, Cast after base has been completed.
B, Sectioning dies with saw.
C, Dies removed from cast.
D, Dies trimmed and replaced on cast.

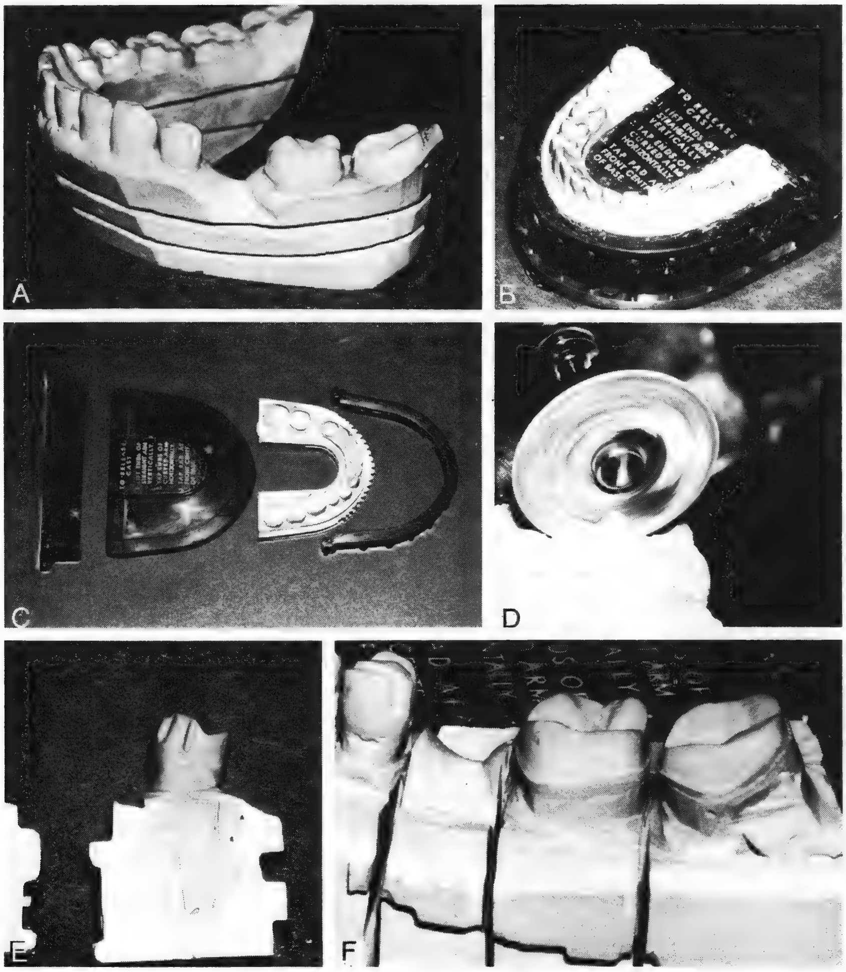

FIGURE 11–9 Di-Lok System

A, Cast prepared to fit into Di-Lok.
B, Stone poured into tray and cast seated into stone.
C, Apparatus disassembled and cast removed.
D, Sectioning with disc.
E, Premolar die trimmed.
F, Dies replaced in Di-Lok.

12

The Pontic

A pontic is the artificial tooth in a fixed partial denture that replaces the lost natural tooth. Usually it is suspended between cast abutment restorations by means of rigid metal connectors, either soldered or cast. The pontic may be made entirely of one material such as cast gold (Fig. 12–1), or porcelain can be fused directly to a metal casting (Fig. 12–2) (as discussed in Chapter 23).

FUNCTIONS OF A PONTIC

A pontic serves to restore mastication and speech, to maintain tooth relationships, both intra-arch and interarch, and to satisfy the patient's esthetic and psychologic need to eliminate spaces in the dentition.

MASTICATION AND SPEECH

The pontic provides hard surfaces against which food can be chewed by teeth in the opposing arch. It also helps to prevent large pieces of food from lodging in an edentulous space in which the tongue and cheek cannot perform the function of returning partially chewed food to the occlusal surfaces for further chewing.

A space created by the loss of a tooth alters the pattern of airflow, making normal speech difficult. A pontic helps to restrict air passage through an edentulous area to aid in the reestablishment of normal sounds.

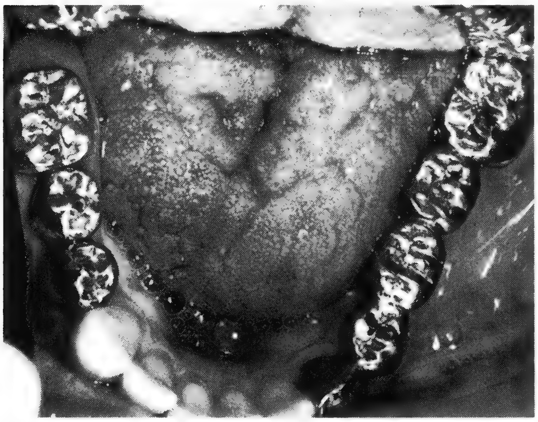

FIGURE 12–1 Mandibular left fixed partial denture utilizing cast gold pontic.

FIGURE 12–2 Maxillary fixed partial denture utilizing canine metal-ceramic pontic.

MAINTENANCE OF TOOTH RELATIONSHIPS

When missing teeth are not replaced, the teeth posterior to edentulous areas can move forward from their normal position and assume an anteriorly tipped position. The teeth can tip faciolingually or rotate as they move out of position. It is also possible for teeth anterior to and opposing edentulous spaces to drift distally and occlusally into the open area. These abnormally positioned teeth may be subjected to excessive masticatory forces and often produce occlusal interferences during chewing. Such occlusal abnormalities may result in excessive tooth mobility or temporomandibular joint disturbances. In addition, the periodontal health of adjacent and opposing teeth is compromised by the difficulty of cleaning all the surfaces of malpositioned teeth and by the tendency for food impaction resulting from loss of normal proximal contact relationships.

Pontics maintain the integrity of the dental arches by preventing teeth that are adjacent to and opposing an edentulous area from moving out of their normal relationships.

ESTHETICS

Dental esthetics affects personal appearance. The presence of a full complement of teeth with a natural appearance is important to an individual's self-image. Pontics fill in the empty spaces that would be observed during smiling and talking and provide support for the lips and cheeks to allow normal facial form.

Pontics fabricated from porcelain have a range of colors that can be matched to most natural teeth. The color of the facing is selected by comparing different colored samples of porcelain, provided by the manufacturer, with the natural teeth. The process of shade selection is discussed in detail in Chapter 24.

FORM OF A PONTIC

Pontic form is determined by requirements related to mastication, speech, esthetics, and the maintenance of periodontal health. At times, these objectives may conflict with each other.

If food is to be effectively chewed, the pontic must be positioned and shaped so that it interdigitates with the opposing dentition. It also must be located in the normal position of the missing natural tooth and possess similar dimensions in order to reestablish normal enunciation.

In order to satisfy esthetic demands, when restoring an edentulous space that is readily visible, the pontic should closely resemble the size, contour, and color of the tooth being replaced.

Pontic form should promote the maintenance of periodontal health by allowing easy access to the soft tissue for oral hygiene procedures. The relationship of the pontic to the proximal gingiva and its contact with the edentulous ridge tissue require careful planning in order to provide an esthetic result and access for cleaning (Fig. 12–3).

RELATIONSHIP OF THE PONTIC AND SOFT TISSUE

The pontic should not encroach on the normal cervical embrasure, since this space is necessary to allow access during oral hygiene procedures.

FIGURE 12–3 Metal-ceramic fixed partial denture replacing maxillary canine. Incisal view shows limited lingual ridge contact to allow access for cleaning.

FIGURE 12–4 Cervical dimensions of pontic have been reduced to allow better access for cleaning proximal surfaces of abutment teeth and edentulous ridge tissue.

When esthetic need does not require normal tooth size, it is hygienically advantageous to enlarge the proximal embrasures by reducing the cervical dimensions of the pontic. This approach permits better access for cleaning of the proximal surfaces of the prosthesis and the soft tissue with floss or a special brush (Fig. 12–4).

The solder joints between the pontic and the abutment retainer should not contact the interdental papilla, since this prevents proper cleaning and promotes gingival inflammation (Fig. 12–4).

Contact of the pontic with the ridge tissue over an area comparable to the cervical dimensions of the natural tooth being replaced appears to be logical but produces a concave tissue contacting surface that cannot be totally cleansed with dental floss. Therefore, to promote soft tissue health through cleansability, there should be minimal contact of the pontic with the edentulous ridge tissue. However, to develop normal tooth form for an esthetically critical pontic, there must be some contact with the ridge tissue to prevent unnaturally dark areas from appearing at the cervical aspect.

A deviation from normal tooth form that promotes the cleansability of a pontic is the limitation of ridge contact to the cervical aspect of the facial surface. This prevents the formation of a concavity, thus allowing cleansing with dental floss. Another alteration that satisfies the esthetic need for natural tooth form, while providing reasonable access for oral hygiene procedures, is to accurately adapt the pontic to the facial portion of the ridge only and to terminate the adaptation at the crest of the ridge. This enlarges the lingual embrasure and allows lingual access to the underlying soft tissue.

Pontic contact with the ridge tissue should be passive. Pressure tends to promote tissue hyperplasia owing to the patient's inability to clean effectively or to rinse under the pontic.

All materials contacting the ridge tissue should be dense, smooth, and possess a high degree of surface luster. Glazed porcelain is generally preferred because it is very smooth and has a surface integrity that seems to accumulate less plaque and allows easy cleansing. Dense cast metal that is well polished is also satisfactory.

TYPES OF PONTICS

From the previous discussion of pontic form, it is apparent that pontics are shaped differently in estheti-

FIGURE 12–5 Mandibular fixed partial denture utilizing a sanitary pontic form.

cally critical areas than in nonvisible areas in which the form is altered to enhance cleansability. As a result, there are two main types of pontics based on their form: sanitary and anatomic. The sanitary, or hygienic, design reproduces occlusal morphology while establishing a cervical form that is convex in all directions and that contacts only the crest of the edentulous ridge (Fig. 12–5). The anatomic design bears a greater resemblance to a natural tooth because it possesses a more nearly normal cervical form.

Types of Sanitary Pontics

All-Metal

An all-metal sanitary form of pontic can be used, and is particularly advantageous in situations in which the occlusocervical or mesiodistal dimension of the edentulous space is limited and the use of porcelain is not required for esthetic reasons (Fig. 12–5).

Metal-Ceramic

When esthetic considerations take precedence, a sanitary form of pontic may be fabricated by fusing porcelain directly to the metal pontic while retaining the cleansability of a sanitary form for the cervical portion of the pontic (Fig. 12–2). The fabrication of metal-ceramic pontics is discussed in Chapter 23.

Occlusal Bar

This type of pontic does not contact the edentulous ridge (Fig. 12–6). It is generally used when the edentulous space is very small mesiodistally, large occlusocervically, or both. In such instances, the usual form of pontic having ridge contact would seriously restrict access to the cervical embrasures and interfere with proper hygiene. This type of design permits large pieces of food to lodge in the space between the pontic and soft tissue and therefore is at first annoying to patients. However, the food may be dislodged easily by swishing fluids through the larger space.

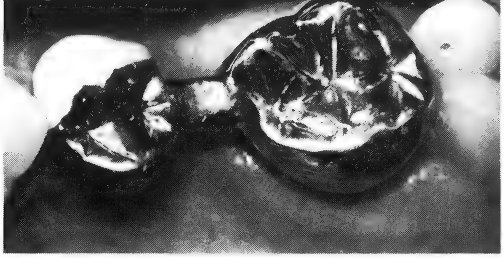

FIGURE 12–6 Occlusal bar type of pontic.

Types of Anatomic Pontics

The Metal-Ceramic Pontic

An anatomic form of pontic may be fabricated by fusing porcelain directly to a metal casting (as is described in Chapter 23).

The Reverse Pin Pontic

This facing is cemented to a casting that has metal pins made to fit holes that have been drilled into the back of the porcelain facing. Usually the ridge-contacting surface of the pontic is formed of both porcelain and metal. This facing is customized from a porcelain denture tooth.

FABRICATING ANATOMIC REVERSE PIN FACINGS

Since these facings are generally made from porcelain denture teeth, the manufacturer's mold and shade guide is used to select a tooth of the right color and one that is slightly larger than the edentulous space.

The lingual one-half of the denture tooth is ground away, and a flat surface is produced. On anterior porcelain denture teeth, this procedure leaves part of the metal retentive pins in the back, which presents no problem, since the holes will be drilled in the porcelain surrounding the remnants of these pins. On posterior teeth, it is not necessary to eliminate all of the depression left by the retentive diatoric hole.

The denture tooth is ground to the required dimensions, anatomic form, and ridge contact. With the facing properly aligned, a facial plaster index is made so the facing can be properly oriented during the waxing process (Fig. 12–7).

The location for each of the holes to be drilled in the porcelain is marked with the point of a pencil on the flat lingual surface. The four to five pinholes should be separated as widely as possible and placed in the bulkiest part of the facing. They should be 1.5 mm deep with 1.0 mm of porcelain remaining beyond the depth of the hole. It is advisable to measure the thickness of the facing at the proposed drilling sites to verify that there is an adequate thickness of porcelain.

The facing is securely embedded in dental compound so that only the marked lingual surface is exposed. It is advantageous to embed the facing in a slight depression so that a lubricant can cover the facing. Carbide drills between 0.5 and 0.7 mm may be purchased or made from old carbide burs. To avoid cracking the facing, the holes should be drilled at high speed with intermittent light pressure. The holes can be drilled by hand, but the use of a small drill press or surveying instrument ensures alignment of all the holes. For efficient and safe drilling, it is mandatory that a lubricant flood the area and be in contact with the drill at all times. Handpiece cleaner is a good lubricant for this purpose (Fig. 12–8).

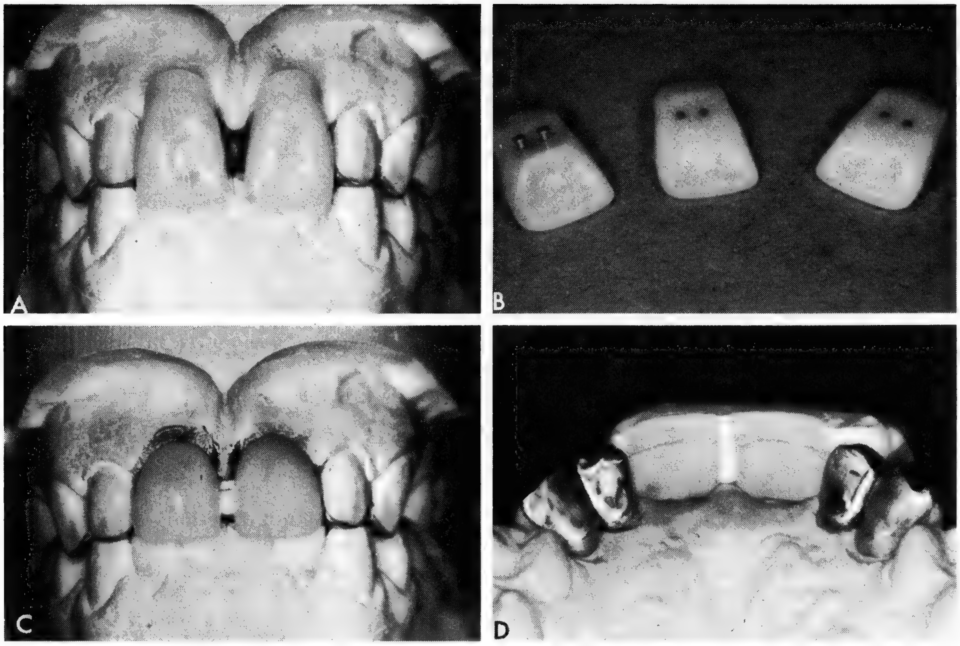

FIGURE 12–7 Shaping a Reverse Pin Facing

A, Denture teeth on cast prior to grinding.
B, Lingual surface and pins reduced to provide a flat area.
C, Facings shaped and adapted to edentulous ridge.
D, Lingual view showing incisal bevel placed to provide a thickness of metal to protect facing from occlusal forces.

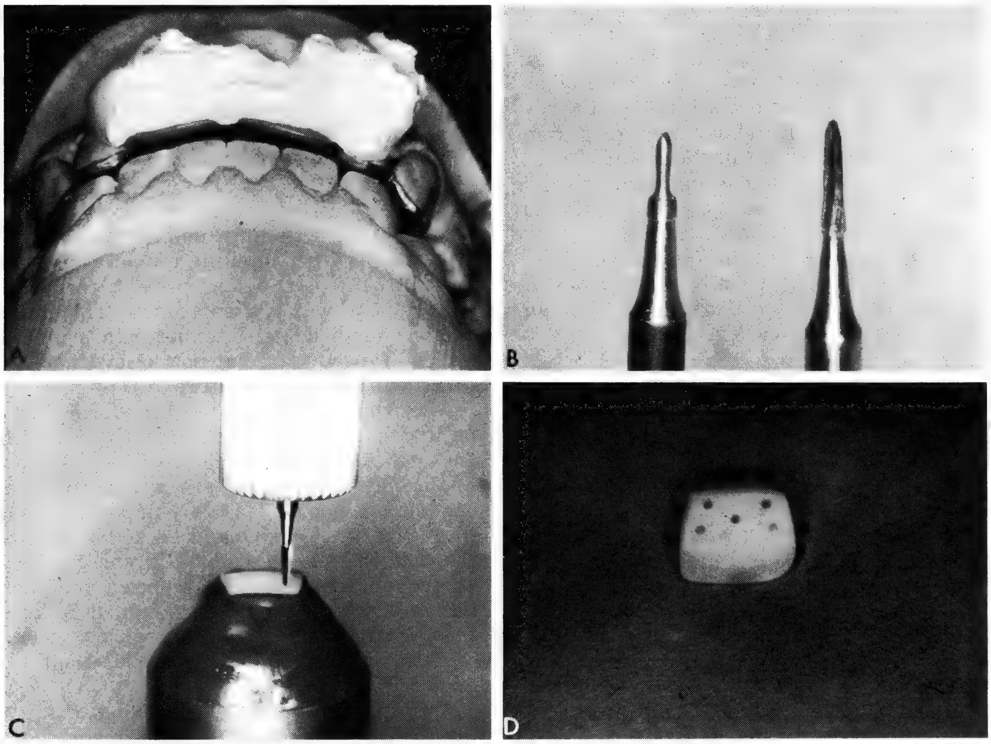

FIGURE 12–8 Drilling the Holes for a Reverse Pin Facing

A, Indexed facing showing clearance with opposing teeth.
B, Drills used to produce pinhole in facing.
C, Facing held firmly in compound and ready for drilling.
D, Holes completed in facing to a depth of 1.5 mm.

13

Wax Patterns

A cast dental restoration is fabricated by forming a pattern on the die that can then be removed and embedded in a refractory mold material from which it is eliminated by the use of heat. Molten metal is cast into the resulting cavity in the mold. Wax is an ideal pattern material because it is easily shaped and can be readily and completely eliminated by heat.

The pattern should be an accurate reproduction of the missing tooth structure, since it forms the outline of the mold into which the gold alloy is cast. The casting can be no more accurate than the wax pattern, regardless of the care observed in subsequent procedures.

DIRECT AND INDIRECT WAXING

Prior to the advent of indirect procedures for producing dental castings, wax patterns were formed directly on prepared teeth in the mouth or made on dies from tube impressions and then refined in the mouth. These procedures presented many technical complications and limitations and are not often used, except for simple patterns such as those for a cast post and core.

Indirect fabrication of a cast restoration involves shaping of the wax pattern on a die, usually gypsum, which is a replica of the prepared tooth obtained from an elastic impression made in the patient's mouth.

WAXES—THEIR PHYSICAL PROPERTIES AND HANDLING CHARACTERISTICS

American Dental Association Specification no. 4 divides dental casting waxes into three types: Type A, a hard or low-flow wax that is rarely used except in some indirect techniques; Type B, a medium wax employed in direct techniques; and Type C, a soft wax used for indirect techniques for construction of inlays and crowns. Somewhat different properties are required for the various types.

The exact composition of dental waxes is rather guarded by the manufacturers. However, the essential ingredients are paraffin wax, gum dammar, and carnauba wax, with some coloring material. All of these substances are of natural origin, being derived from either mineral or vegetable sources.

Paraffin is the main ingredient. It is derived from high–boiling-point fractions of petroleum. By itself it tends to flake when carved and does not leave a smooth surface. Gum dammar is a natural resin from a specific variety of pine. When added to paraffin, it helps resist flaking and allows for a smooth surface. Carnauba wax comes from a tropical palm and is quite hard. It tends to decrease the flow of a wax. Carnauba wax is now being largely replaced by synthetic waxes.

Dental wax should be capable of being carved to the thinnest margin without distortion, flaking, or chipping. The color of the wax should be in sharp contrast to that of the die material to aid in visibility during carving. The wax should vaporize as completely as possible without leaving a residue when being eliminated from the mold.

Waxes do not solidify with a definite space lattice as does a metal. Instead, the structure is more likely to be a combination of crystalline and amorphous materials, displaying limited ordering of the molecules. The wax lacks rigidity and may flow under stress even at room temperature.

Flow or plasticity of the wax is necessary when it is heated to its softening temperature. In the case of a Type B wax, the softening temperature must be tolerated without pain by the patient. On the other hand, since Type C wax is used at room temperature with the indirect method, its softening point can be lower than that of Type B wax, but not so low that the wax flows unduly at room temperature.

After the wax pattern has been formed on the die, the pattern must, of course, be withdrawn from the die before it is invested. If the wax flows during the removal of the pattern, the pattern will be distorted and the casting will not fit. It is very important, therefore, that the flow of the wax should be as low as possible while the pattern is being removed from the die and during subsequent handling. The composition of the wax should be regulated to achieve this end. It is for this reason that the flow of the wax at various temperatures is strictly specified in the American Dental Association Specification no. 4.

As previously noted, the first opportunity for distortion of the wax pattern occurs during its withdrawal from the die. During subsequent manipulations, it is possible that the pattern may be further distorted by handling, but with proper care such distortions can be kept to a minimum.

As with any thermoplastic material, probably the chief cause of distortion is the relaxation of stresses that are induced during manipulation. There are a number of factors that may cause distortion and that are under the control of the operator, but they cannot be entirely eliminated. For example, if the wax is not at the same temperature throughout when it is adapted to the cavity, some parts of the wax pattern may contract thermally more than others, and stresses are introduced. If the wax is not held under uniform pressure during cooling, it is possible for some of the molecules to be compressed more closely together than others. Here again, when relaxation occurs, a distortion may take place. If melted wax is added to the pattern in order to repair some parts that were not accurately obtained or to repair a damaged area, the added wax will introduce stress during cooling. During the carving operation, some of the molecules of the wax will undoubtedly be disturbed, and a stress will result.

It may be necessary to perform all these operations during fabrication of the pattern. If a technique can be used by which the amount of carving, the amount of change in temperature, and similar factors can be minimized, the subsequent relaxation and warpage of the pattern can be limited.

Once the pattern has been obtained, the entire distortion effect can be minimized if the temperature of the pattern is not changed and if it is surrounded by the hard investment as soon as possible after it has been removed from the die. It should always be the rule to invest the pattern as soon as possible after it has been finished. Once the pattern is surrounded by the hardened investment, no further distortion can occur. The wax may be eliminated and the casting made at any time that is convenient.

WAXING INSTRUMENTATION

Several types of instruments are needed to form wax patterns. A set of instruments* specifically designed for the cone waxing technique was designed by Dr. Peter K. Thomas (PKT numbers 1 to 5) (Fig. 13–1A). Other useful instruments include a Darby-Perry trimmer† (DPT number 6) (Fig. 13–1B), a number 7 wax spatula (Fig. 13–1C), and a double-ended brush‡ (Fig. 13–1A).

Each of these instruments has a specific use. The PKT number 1 instrument is designed for the application of large drops of melted wax (Fig. 13–2A), and the number 7 wax spatula is used to apply even larger amounts. The instrument tip is heated in a Bunsen burner flame, pressed into the wax (Fig. 13–2B), and then lifted out of the wax. Wax adheres to the instrument (Fig. 13–2C), and the tip can then be passed quickly through the flame so a drop of molten wax is formed on the instrument tip (Fig. 13–2D).

The rounded end of the PKT number 2 instrument is used to apply small drops of wax. The sharp explorerlike end is used to smooth rough areas by making the wax reflow (Fig. 13–3). The PKT number 3 instrument is used to carve grooves on the occlusal surface of posterior teeth (Fig. 13–4A). The PKT number 4 instrument is designed as an all-purpose carver (Fig. 13–4B). The PKT number 5 instrument is used to refine triangular ridges and occlusal grooves (Fig. 13–4C). The double-ended brush serves two purposes, with the stiff end being used to remove loose particles of wax from the pattern during

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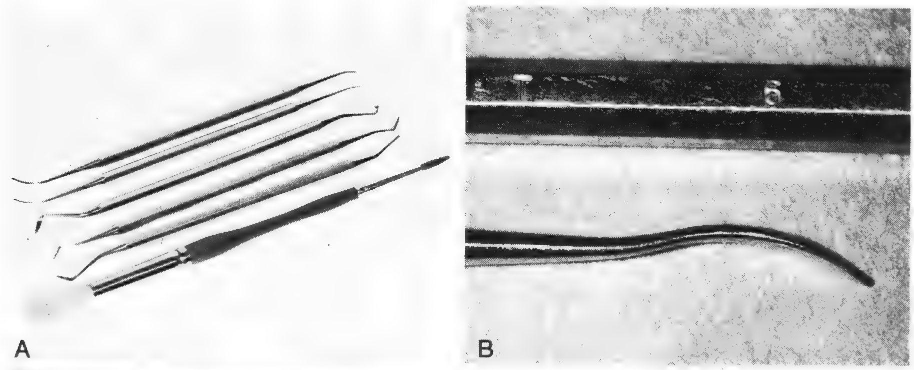
*O. Suter Dental Manufacturing Co., Chico, CA 95926.
†HuFreidy Co., Inc., Chicago, IL 60018.
‡Plate brush, Whip-Mix Corp., Louisville, KY 40217.



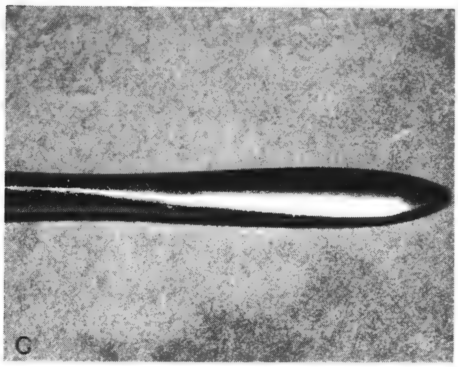


FIGURE 13–1 Waxing Instrumentation

A, PKT waxing instruments and Whip-Mix double-ended plate brush.
B, Darby-Perry marginal trimmer.
C, Small end of number 7 wax spatula.

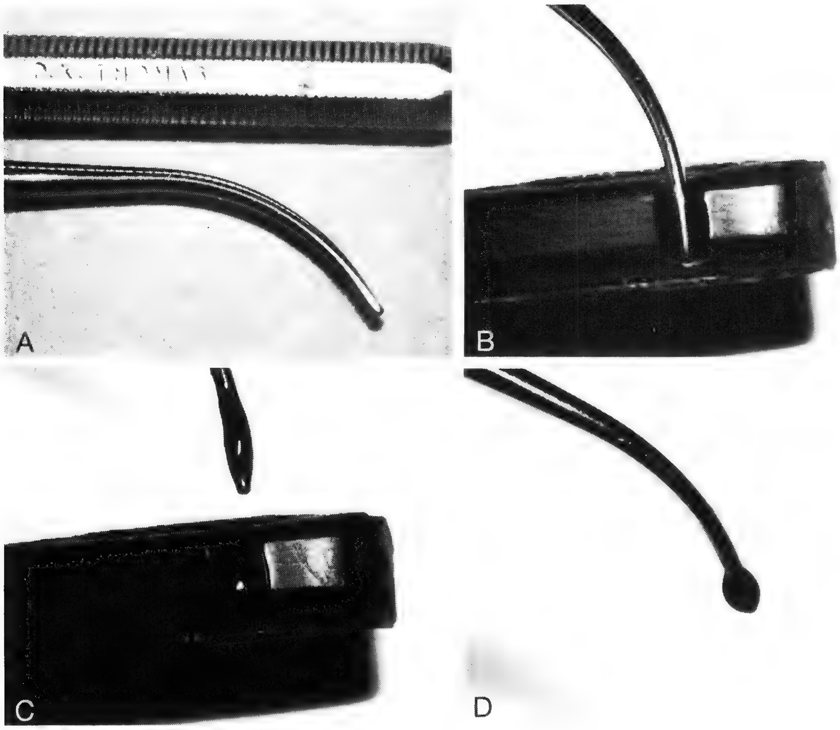


FIGURE 13–2
A, Large end of PKT number 1 instrument.
B, Warm instrument being pressed into stick of wax.
C, Wax adhering to instrument.
D, Formation of a drop of wax by passing the instrument quickly through the Bunsen burner flame.

carving. The more flexible end is used to apply a powder to the occlusal surface to clearly delineate occlusal contacts with opposing surfaces (Fig. 13–4D). The Darby-Perry carving instrument (DPT number 6) has a blunted blade, which is used to refine wax pattern margins (Fig. 13–1B).

POSTERIOR FULL VENEER WAX PATTERNS

Forming the Initial Pattern Thickness

Since the wax pattern must be removed intact from the stone die in order to be invested and cast, a lubricant is applied to prevent the molten wax from sticking to the stone die. The lubricant can be applied with a brush, or the stone die can be suspended in a container of lubricant so the preparation portion of the die can soak up the lubricant. With either technique, prior to wax application excess lubricant on the surface must be blown off with a gentle stream of air. Excess lubricant interferes with accurate adaptation of the wax to the die and causes defects, such as lines and voids on the internal aspect of the wax pattern.

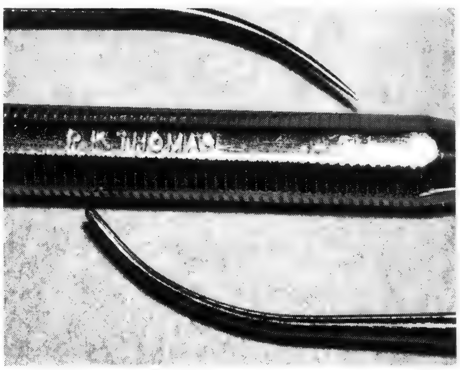


FIGURE 13–3 PKT instrument number 2 showing both the sharp end used for wax reflowing and the small rounded end for the application of small increments of wax.

The initial application of wax to the die should produce a bulk sufficient to allow the pattern to be removed and inspected without breakage or distortion. This can be accomplished best by dipping the lubricated die into molten wax to obtain a thin film that uniformly contracts around all the prepared surfaces as the wax cools (Fig. 13–5). After this initial thin layer has cooled, the die is dipped additional times to achieve an approximate dimension of 0.5 to 1 mm of wax to provide adequate bulk for removal without distortion.

Dipping of a die does not build sufficient thickness if the wax is too hot, since most of the molten wax runs off before it congeals. By melting the wax in a metal container over a Bunsen burner, it is possible to experimentally determine the correct temperature for a given wax. Commercially available wax heaters* (Fig. 13–6) can be set to the proper temperature for dipping. This is a great convenience and avoids adversely affecting the physical properties of the wax as a result of overheating. Reference to the melting range of the wax is necessary in order to properly set the temperature for the heater.

The initial dipping should be done by quickly sub-

*Williams Company, Buffalo, NY 14214.

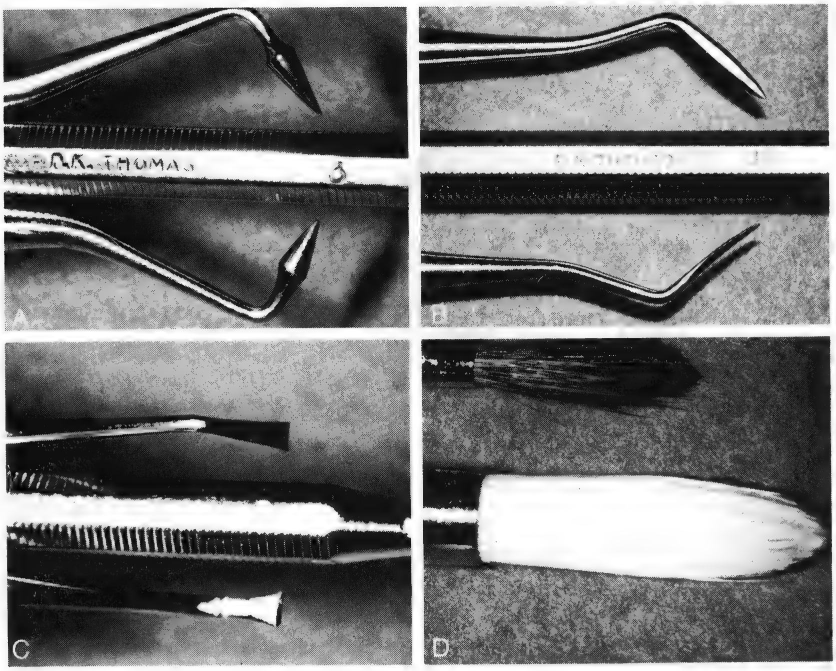


FIGURE 13–4

A, Number 3 waxing instrument with cone-shaped tips.
B, All-purpose sharp bladed wax carving instrument.
C, PKT instrument number 5.
D, The two ends of the plate brush.

mersing the die in the molten wax to a point at least 2 mm apical to the most cervical portion of the margin. Rapid dipping produces a uniformly well-adapted pattern without incremental lines on the internal surface of the pattern. A pattern produced by dipping slowly and tentatively often contains incremental lines on the internal surface as a result of cooling and shrinkage of a portion of the wax before the rest of the die is covered. Additional dippings, to obtain more bulk, should also be done rapidly to prevent remelting of the previous layer of wax.

Picking up and applying wax with an instrument, such as the PKT number 1 instrument or the larger number 7 wax spatula, is an alternative to dipping the die. Adding of increments of wax in this manner can work for experienced individuals but is often troublesome for the beginner, since it can lead to internal creases or other defects in the wax pattern. These defects are produced when additional increments of wax fail to coalesce with wax that has cooled from a previous application. Such defects are a concern, since they are evidence of poor internal adaptation of the pattern. Also, they tend to trap air bubbles during the investing process, producing positive irregularities on the internal surface of the casting. These imperfections, if allowed to remain, interfere with seating the casting.

The initial bulk of wax is allowed to cool for several minutes to allow stabilization of the wax so it will not be easily distorted when it is handled. The pattern should not be placed in hot areas such as under a lamp or near a burnout furnace.

Initial Margin Adaptation and Removal

The wax that is cervical to the margin of the die is removed by using a blunt instrument such as a DPT number 6 or a small beavertail burnisher (Fig. 13–7). Warming the instrument by passing it quickly through a Bunsen burner flame helps to avoid chipping or cracking of the wax. An overly hot instrument should be avoided, since it remelts the wax and produces distortion.

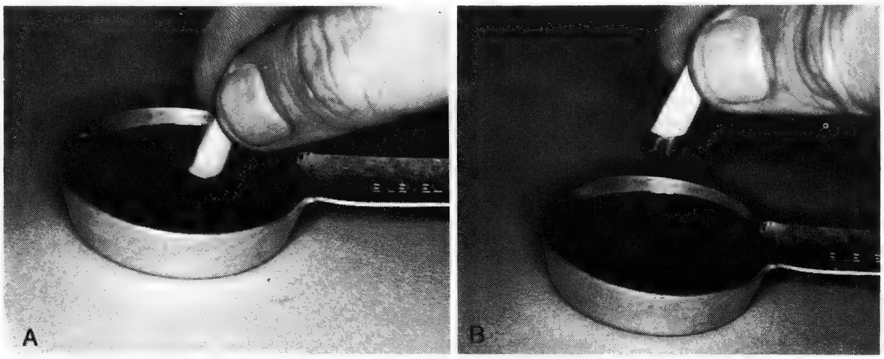


FIGURE 13–5 Dipping the Die

A, Die being dipped into molten wax.
B, Film of congealed wax on die surface after removal from molten wax.

FIGURE 13–6 Williams Hot Rod wax heater.

The use of a sharp instrument is not recommended because it can abrade the marginal area of the die and lead to a casting that does not completely cover the prepared portion of the tooth.

Careful removal of the wax pattern is necessary to prevent crushing of the pattern. A piece of rubber dam that has been washed and dried can be placed between the fingers and pattern to facilitate removal of the pattern without damage.

The pattern should not crack on removal, and when reseated on the die it should exhibit no distortion. Any repeated cracking or distortion of the pattern upon removal or reseating is related either to faulty removal technique or to an undetected undercut in the tooth preparation. The presence of an undercut necessitates further refinement of the tooth preparation, which requires a new impression, die, and working cast.

Posterior Cone Waxing Technique

The science of tooth morphology consists of a myriad of small details. An inexperienced person often becomes lost in these details when attempting to reproduce the entire shape of a tooth in one operation. For this reason, it is best to create the form of a tooth in a definite sequential procedure whereby the number of items that must be evaluated at each stage is reduced, thereby making it easier to detect errors in form, size, or location. The *cone waxing* or *wax added* technique accomplishes this goal by creating the shape of the tooth in small stages. This procedure is described as the technique of first choice in waxing. The technique involves the following sequential stages: axial contour (Fig. 13–8A, B), cusp cones (Fig. 13–8C, D), marginal and cusp ridges (Fig. 13–8E, F), facial and lingual contours (Fig. 13–8G, H), triangular ridges (Fig. 13–8I), and completed wax pattern (Fig. 13–8J).

FIGURE 13–7 Proper orientation to the finish line when using the DPT 6 instrument for cervical wax removal.

Axial Contour

The axial contour of a tooth is its most peripheral form. Figure 13–9 shows an occlusal view of the representative axial contour for each posterior tooth. This step in wax pattern formation involves reproduction of the cervical form of the tooth from the proximal contact to the gingival finish line.

Producing the proper axial contour is extremely important to the periodontal health of the patient, since cervical overcontouring of a restoration promotes plaque accumulation, which in turn causes gingival inflammation. The wax pattern and the resulting restoration must be a continuation of the contour of the natural tooth.

The first step in developing the axial contour is the location of the proximal contact areas. The proper location on the wax pattern is determined by examining the proximal surfaces of adjacent teeth or by referring to the morphologic characteristics of unrestored teeth. There are no all-inclusive rules for the position of proximal contacts on posterior teeth. A knowledge of normal tooth morphology and the form of remaining unrestored natural teeth are used as guides. About one-half of the proximal contacts of posterior teeth are located in the occlusal one-third of the crown and the remainder in the middle one-third. Proximal contacts also vary in their faciolingual location. They are located either facially to the center or in the middle of the tooth.

Using the PKT number 1 waxing instrument, wax is added to the initial pattern to extend the contour toward the contact area of the adjacent tooth (Fig. 13–10A). While the wax is still soft, the pattern is positioned on the working cast to allow the adjacent tooth to displace any excess wax and thereby locating the contact area. Any excess wax is carved away with the PKT number 4 instrument to create the proper contact form. If contact is not achieved with the first application of wax, the pattern is removed from the working cast, and additional wax is added until contact is made.

Complete proximal contour is achieved by filling in the cervical area between the proximal contact extension and the margin of the preparation, with care taken that proper embrasure form is established (Fig. 13–10B). The remainder of the axial contour is completed by adding wax to the facial and lingual surfaces so that they are continuations of natural tooth form (Fig. 13–10C). Looking down the line of teeth from an anterior or posterior vantage point helps to verify the proper contour and to identify areas that need further refinement. After completion of the axial contour, the wax pattern should resemble a tooth from which the occlusal one-half has been removed (Fig. 13–10D), with sufficient occlusal clearance to allow easy execution of the steps forming the occlusal surface.

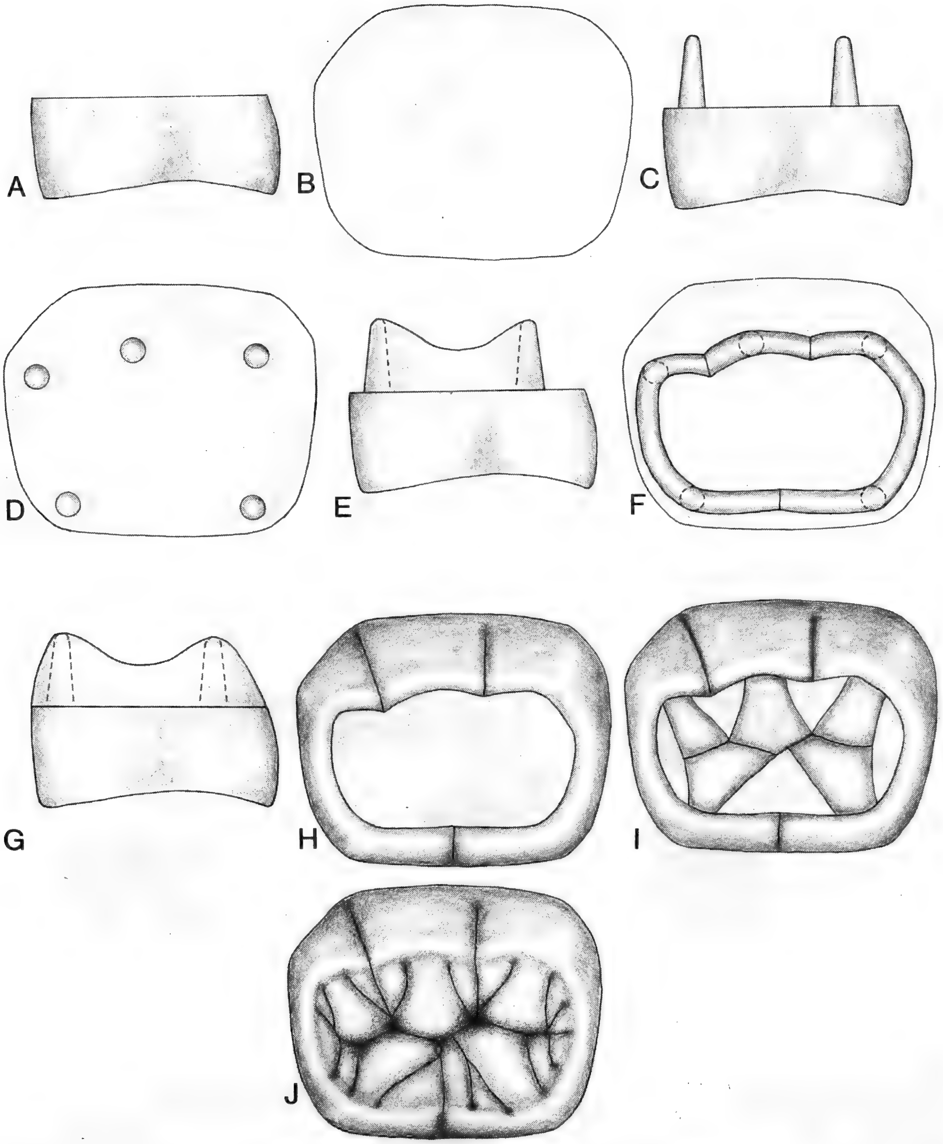


FIGURE 13–8 Posterior Cone Waxing Technique

A, Axial contour, proximal view.
B, Axial contour, occlusal view.
C, Cusp cones, proximal view.
D, Cusp cones, occlusal view.
E, Marginal and cusp ridges, proximal view.
F, Marginal and cusp ridges, occlusal view.
G, Facial and lingual contours, proximal view.
H, Facial and lingual contours, occlusal view.
I, Triangular ridges, occlusal view.
J, Completed pattern, occlusal view.

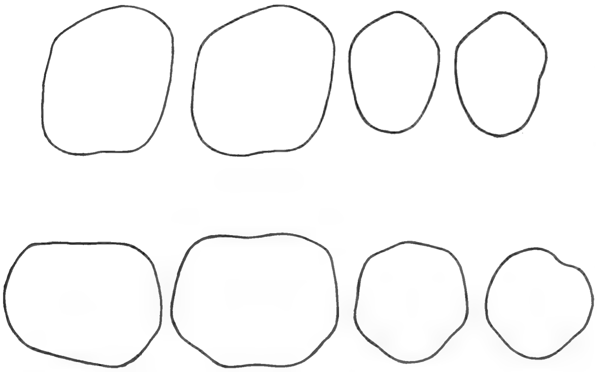


FIGURE 13–9 Diagrammatic representations of posterior contours in horizontal cross-section.

The upper drawings represent maxillary premolars and molars. The lower drawings represent mandibular premolars and molars.

Cusp Cones

Wax cones are placed on the pattern to determine the location and height of cusp tips.

Two patterns of cusp placement are used in fabrication of fixed partial dentures. These patterns are differentiated from each other on the basis of where the working cusps contact the opposing dentition. The working cusps of posterior teeth are the cusps that fit into the central portions of the occlusal surfaces of the opposing teeth and that perform the work of chewing in a mortar-and-pestle–like manner. In normal occlusion, the working cusps are the lingual cusps of the maxillary posterior teeth and the facial cusps of the mandibular posterior teeth.

The first cusp pattern, called "cusp-marginal ridge," is that found most commonly in properly developed natural dentitions. It is an arrangement of teeth in which the cusp of one tooth contacts two teeth in the opposing arch. This is sometimes referred to as a "tooth-to-two-tooth" relationship. Some working cusps contact the marginal ridges of opposing dentition, and others make contact in fossae in the opposing arch.

The second pattern of cusp placement is one in which all working cusps fit into fossae in the opposing dentition. This arrangement is called a "cusp-fossa" occlusion. Since each tooth contacts only one tooth in the opposing arch, it also may be referred to as a "tooth-to-one-tooth" relationship.

The pattern of cusp placement chosen for a specific clinical restoration depends on several factors. The position of the opposing tooth and its morphologic features may dictate whether a cusp can be placed into a fossa or in opposition to a marginal ridge. When opposing teeth are being restored simultaneously, there is more control over positioning of the cusps. However, control is limited, since a desired change in the occlusal form cannot always be achieved without affecting axial contour and its potential to impair periodontal health.

Mandibular movements can also dictate a specific

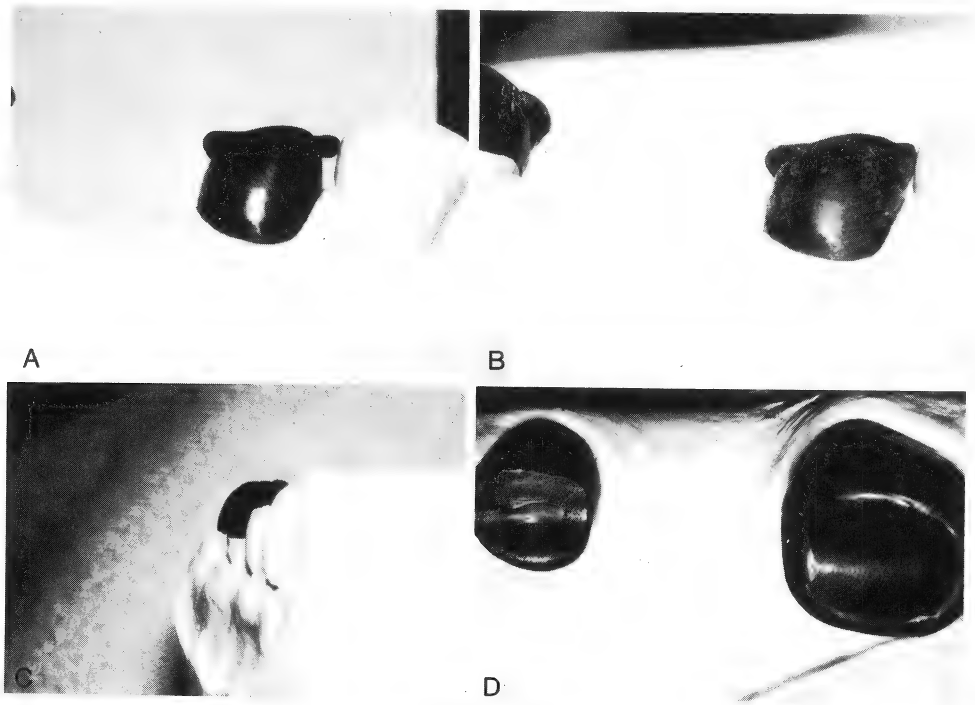


FIGURE 13–10

A, Wax extended to the proximal contact areas.
B, Completed mesiocervical wax pattern contour.
C, Facial axial contour is a continuation of normal tooth contour.
D, Occlusal view of completed axial contour.

location for a cusp in order to provide a harmonious occlusal relationship during chewing. Normally, the anterior teeth influence eccentric mandibular movements and prevent posterior tooth contact in working, nonworking, and protrusive movements. The waxing procedures described in this chapter are consistent with this type of anterior guided occlusion. However, the existing wear patterns present in certain mouths may require the use of a group function occlusion in which some posterior tooth contact is present in a working movement. These situations require modifications to the described procedures for checking the wax pattern in eccentric mandibular movements.

The cusp-marginal ridge form of occlusion is the type most often used in routine fixed prosthodontics, but the cusp-fossa relationship is used in certain clinical situations and has some advantages. The cusp-fossa arrangement enhances occlusal stability through the production of a tripod of occlusal contacts for each working cusp. The forces of occlusion are better aligned over the axes of teeth, and since there are no occlusal contacts against adjacent marginal ridges, there is less potential for interproximal food impaction. Cusp-fossa occlusion and waxing are discussed in Chapter 32.

After determining whether the working cusps will occlude against fossae or marginal ridges, marks are placed on the wax pattern where the cusps are to be located, and drops of wax are placed so the position can be visually verified. Each working cusp cone is formed on its mark with a PKT number 2 waxing instrument and extended to a height that contacts the proper area of the opposing tooth. While the wax is still soft, the articulator is closed. A light film of die lubricant applied to the opposing stone cast prevents the wax cone from sticking and being broken when the articulator is opened. In this manner, the opposing tooth is used to displace excess wax and establish the preliminary cone height. Each nonworking cusp cone is then placed over its mark, and its position is verified by comparing the selected anatomic locations with adjacent and contralateral cusp tips. The cone form and height are then refined by carving and adding wax as necessary (Fig. 13–11A). The completed cones should not touch opposing tooth surfaces, since the final contact occurs on ridges that are formed in subsequent steps (Fig. 13–11B). Eccentric mandibular movements should be produced on the articulator to ensure that the selected cusp positions do not produce occlusal interferences.

Marginal and Cusp Ridges

Marginal ridges and cusp ridges connect to form the heights of contour on the peripheral aspect of the occlusal surface. The addition of these ridges to the wax pattern determines the characteristic occlusal form of the posterior teeth and establishes certain occlusal contacts when a cusp-marginal ridge interdigitation is being established.

With a PKT number 2 waxing instrument, a narrow ridge of wax is made to flow between the cusp cones following the proper curvature and possessing the heights and depths characteristic of the occlusal heights of contour on each tooth (Fig. 13–12).

Contacts with opposing teeth can occur on both marginal ridges and cusp ridges. Therefore, closure of the articulator after each addition of wax while it is still soft is necessary in order to displace any excess ridge height. Failure to observe this precaution will result in either an increase in the occlusal vertical dimension or damage to the wax pattern, or both.

For teeth in normal alignment, the marginal ridges of adjacent teeth are at the same height but do not actually touch each other, since they are separated by an occlusal embrasure. The size of this embrasure is determined by the location of the proximal contact and the form of the tooth. Teeth with proximal contacts in the middle one-third of the proximal surface have larger occlusal embrasures than those that have the proximal contacts located in the occlusal one-third.

Facial and Lingual Contours

The contours of the facial and lingual surfaces are completed by filling in the area remaining between the occlusal termination of the axial contour and the marginal and cusp ridges (Fig. 13–13A, B, C, D). Since occlusal contact normally occurs on the facial contours of mandibular teeth and the lingual contours of maxil-

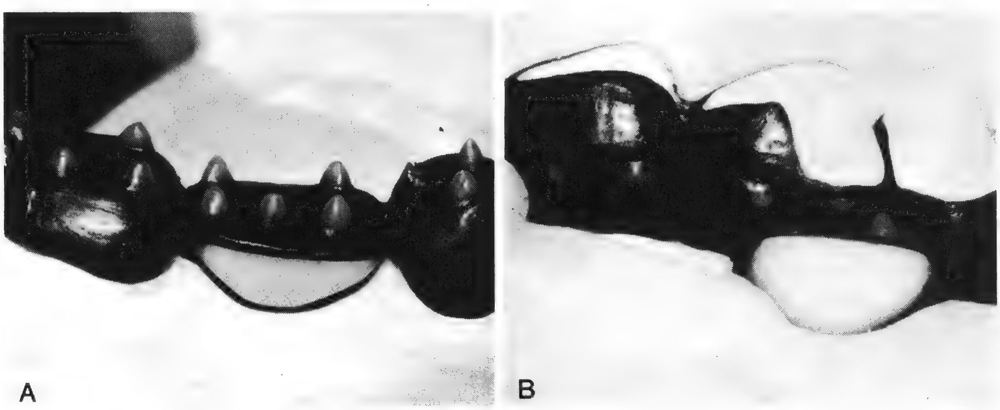


FIGURE 13–11

A, Facial view of completed mandibular cones. Note the relatively symmetric cone form.
B, Facial view of completed maxillary and mandibular cones in centric occlusion.

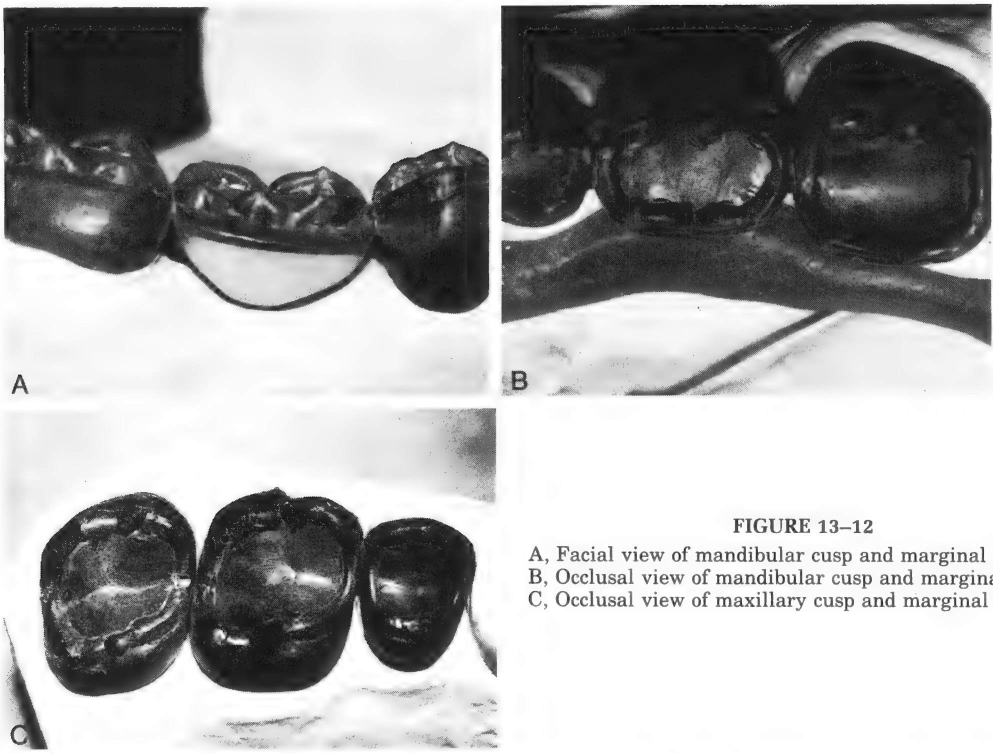


FIGURE 13–12

A, Facial view of mandibular cusp and marginal ridges.
B, Occlusal view of mandibular cusp and marginal ridges.
C, Occlusal view of maxillary cusp and marginal ridges.

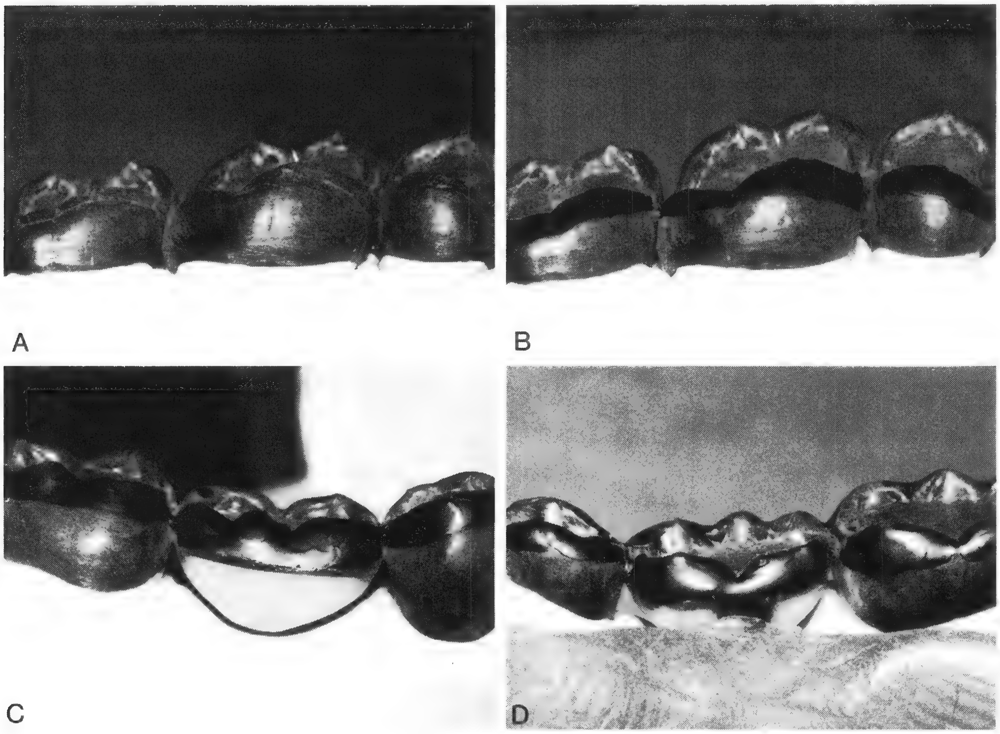


FIGURE 13–13

A, Lingual view of maxillary patterns prior to completion of the lingual contour.
B, Lingual contour completed.
C, Facial view of mandibular facial contour.
D, Lingual view of mandibular lingual contour.

lary teeth, it is necessary to close the articulator after each addition of wax to displace excess wax before it hardens. Once again, looking down the line of teeth aids in evaluating the completed facial and lingual contours.

Triangular Ridges

Although these ridges are not truly triangular, the term is descriptive of the basic shape that is to be achieved. Occlusocervically, these ridges have a triangular form with the base located cervically. Faciolingually the base is located toward the center of the tooth. On unworn natural teeth, these ridges are generally convex in all directions, with the exception of the distobuccal triangular ridge on the mandibular first molar, which can be flat or even concave.

With a PKT number 2 instrument, molten wax is applied near the center of the tooth where the base of the triangular ridge is to be located and is drawn toward the cusp tip to form a ridge of wax (Fig. 13–14). More than one application of wax may be needed to achieve the desired form and bring the ridge into contact with with the opposing tooth. The major objective in forming triangular ridges is to obtain a stability-promoting tripod of contacts around each cusp occluding in a fossa.

As with previous steps, the articulator is closed each time wax is added. If a large amount of wax is displaced, the excess is carved away, the convex form re-established by reforming the ridge with a hot instrument, and the articulator closed again. In closing the articulator, if no mark is left on the wax ridge from the opposing tooth, additional wax is needed. Additions or subtractions are made to the height of the triangular ridge until only a small indentation is formed when the articulator is closed (Fig. 13–15). In this manner, the triangular ridges are established one at a time.

Eccentric mandibular movements are produced on the articulator to check for interferences produced by the height or position of the triangular ridges. Corrections are made if needed.

The final triangular ridge form is dictated by natural tooth morphology, as well as by occlusion. If, in order to obtain contact with the opposing dentition, the ridge is

FIGURE 13–14 Completed Mandibular Triangular Ridges

Note that the base of the triangle is toward the center of the tooth faciolingually. Occlusocervically the ridge is also triangular, with the base located cervically and a convex crest of curvature located occlusally.

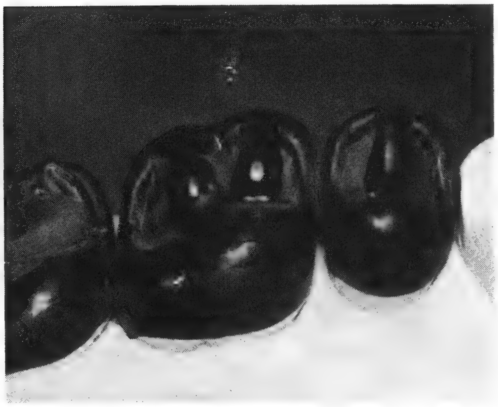


FIGURE 13–15 Indentation produced in the mesiobuccal triangular ridge of the maxillary first molar when the articulator was closed.

built to a grotesque overcontoured form, then repositioning of the ridge is probably indicated. Slight mesiodistal relocation of a ridge often produces occlusal contact with a more normal height and convexity to the ridge. If repositioning the ridge still does not allow both occlusal contact and a normal form, it may be necessary to leave that ridge out of occlusal contact.

Completing the Occlusal Surface

The areas remaining between the major developmental ridges are filled with molten wax by using a PKT number 2 instrument, with the articulator being closed as each area is filled (Fig. 13–16). The wax pattern is then ready for refinement of the occlusal ridge and groove form.

Developmental grooves separate the major cusp areas on the occlusal surface, which are made up of a cusp tip, a triangular ridge, and the smaller supplemental ridges. Supplemental grooves subdivide each cusp area.

The depth and form of these grooves should be determined by applying a knowledge of ideal morphologic characteristics as well as by consulting eccentric mandibular movements, since cusps from opposing teeth pass in and out of these grooves during chewing. In general, the form of developmental grooves tends to be straighter than that of supplemental grooves, which often vary in direction and curvature.

The cone-shaped carver, PKT number 3, is the instrument of choice for creating occlusal grooves. Its tip is used to produce the depth and form of each groove (Fig. 13–17). The sharp edges of wax that surround each newly formed groove are then rounded using a carving instrument such as the PKT number 4. The stiff end of the plate brush is used to brush away loose particles of wax.

After groove formation, the wax pattern is removed from the cast, held up to a bright light, and inspected for thin areas through which light may readily pass (Fig. 13–18). Additional wax is added to deficient areas, since thin wax can lead to an incomplete casting or a casting that is so thin that it may be perforated during finishing and polishing.

Refining of the ridge form is done by heating the sharp tip of a PKT number 2 instrument, making the wax ridge flow up to the surrounding grooves, and then

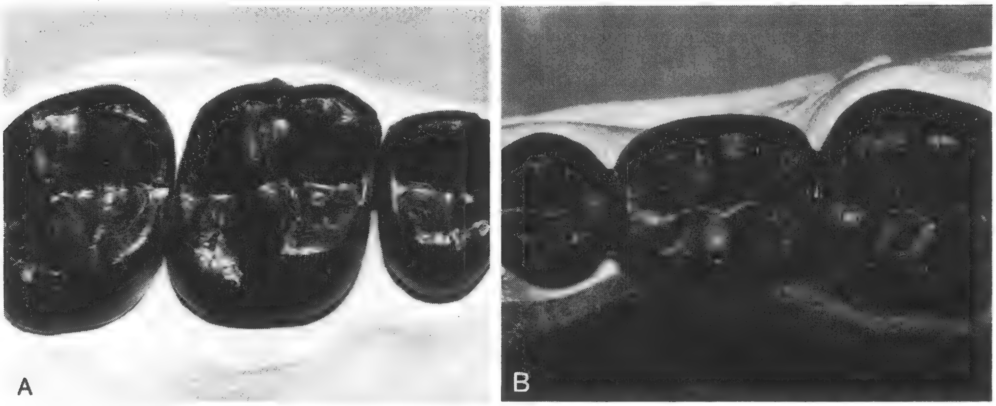


FIGURE 13–16

A, The remainder of the maxillary occlusal surfaces filled with wax.
B, Mandibular occlusal surfaces filled with wax.

pulling the instrument out of contact with the wax. This allows the ridge to assume a smooth convex form as the wax cools (Fig. 13–19). If not used carefully, the hot instrument can cause wax to flow across a groove, in which case the groove must be recarved and the ridge reformed. With some practice in controlling the temperature of the instrument and the time it is left in contact with the wax, nicely formed smooth ridges can be developed.

When triangular and supplemental ridges are refined in this manner, the articulator must be closed each time the wax is made to flow in order to check the occlusal contact relationship. Reflowing of a wax ridge may result in the loss of a previously existing contact or may create a heavy contact with a large dent in the wax. The presence of excessive contact is corrected by carving the ridge, making the wax reflow, closing the articulator, and repeating the process until the ridge is only slightly indented by the opposing tooth. Adding small amounts of molten wax and then closing the articulator can correct the loss of occlusal contact by a similar trial and error method. The entire occlusal surface is refined, and all the occlusal contacts are established by this process.

The location and number of occlusal contacts vary depending on whether a cusp-marginal ridge or cusp-fossa relationship is being established. Occlusal contacts can be located on cusp ridges, triangular ridges, supplemental ridges, or facial or lingual surfaces of the crown.

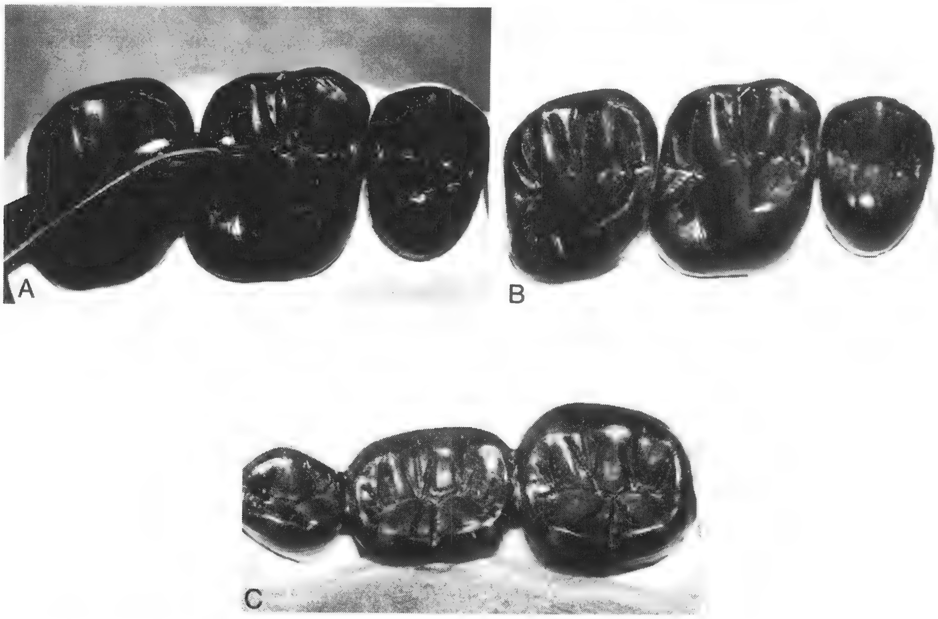


FIGURE 13–17

A, PKT instrument number 3 used to carve occlusal grooves in maxillary first molar wax pattern.
B, All maxillary occlusal grooves carved.
C, Occlusal grooves carved in mandibular patterns.

FIGURE 13–18 Wax pattern held up to a bright light source. Note the perforation in distal fossa.

With cusp-marginal ridge occlusion, three occlusal contacts are established around each working cusp occluding in a fossa and two occlusal contacts (one mesial and one distal to the cusp tip) on each working cusp that contacts marginal ridges.

A cusp-fossa occlusion produces three occlusal contacts around each working cusp in a tripod form. Since all the working cusps occlude in fossae, the total number of contact points achieved is greater than that obtained with a cusp-marginal ridge occlusion.

Applying a light coating of zinc stearate powder to the occlusal surface and tapping the articulated casts together serve as the final check of occlusal contact (Fig. 13–20). The opposing teeth contact the powder and produce marks that permit scrutiny of the uniformity, size, and location of each contact. Zinc stearate powder is used because it burns out during the casting process, without leaving a residue that might produce a rough surface on the casting. After all the centric occlusal contacts have been checked with powder, eccentric movements are generated on the articulator. Enlargement of contact areas indicates that teeth are interfering eccentrically. Necessary corrections can be accomplished by carving, reflowing, dusting with powder, and rechecking the occlusion.

Readaptation and Final Margination

Since some distortion of the wax pattern occurs during handling, the margins must be readapted to the die prior to investing, if an optimal fit of the restoration is to be achieved.

FIGURE 13–19 Occlusal ridges after refinement with the number 2 waxing instrument.

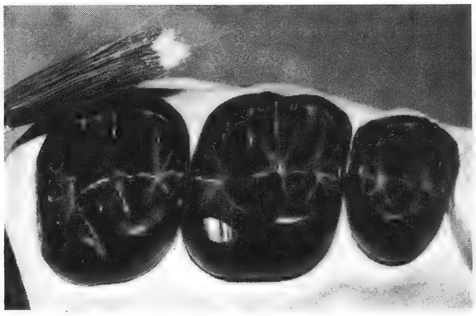


FIGURE 13–20 Occlusal contact marks produced by opposing teeth contacting wax patterns that were coated with zinc stearate powder. The powder was applied with the flexible end of the plate brush.

Prior to final wax readaptation, the die is coated with a thin layer of lubricant, the excess material is blown off with a gentle stream of air, and the wax pattern is fully seated on the die.

Readaptation is accomplished by using a heated instrument to make the marginal wax and the cervical portion of the pattern reflow without disturbing the occlusal aspect (Fig. 13–21A). Additional wax is then added to fill in the resulting depression in the marginal wax and to create a slight excess of wax cervical and lateral to the margin (Fig. 13–21B). A small amount of additional wax is added to each proximal contact area to ensure that there will be adequate contact of the casting with adjacent teeth following metal polishing. At this point, the die and attached wax pattern are set aside for several minutes so the wax can stabilize.

After pattern stabilization, the cervical excess wax is removed with a blunt instrument, such as the DPT number 6 or a small beavertail burnisher (Fig. 13–21C). The rounded blade helps prevent the margin of the die from being abraded. Warming the instrument slightly, without getting it hot enough to melt the wax, aids in the removal of the excess wax without producing chipping or flaking. Keeping the instrument blade in contact with the die cervical to the margin prevents excessive wax removal and serves as a guide to establishing the proper cervical contour.

After marginal adaptation is complete, the cervical area of the pattern must be critically evaluated. Rotating the pattern under a light source so reflection passes across the margin aids in the visual evaluation. The use of magnification up to 15 times can also be helpful to detect deficiencies.

There should be no cervical overcontouring of the pattern, no minute concavities or ridges of wax near the margin, and no areas in which the wax is short of the margin or extends beyond the prepared tooth structure. The wax in this area must be well contoured and smooth, since extended polishing of a casting near the margin generally adversely affects the marginal fit of the casting. It is important to understand that the raw casting will fit no better and be no smoother than the wax pattern.

When the completed wax pattern has passed visual scrutiny, it is removed from the die so that the internal adaptation can be inspected. All grooves and internal detail should be reproduced, and there should be an absence of voids and incremental lines. The pattern is

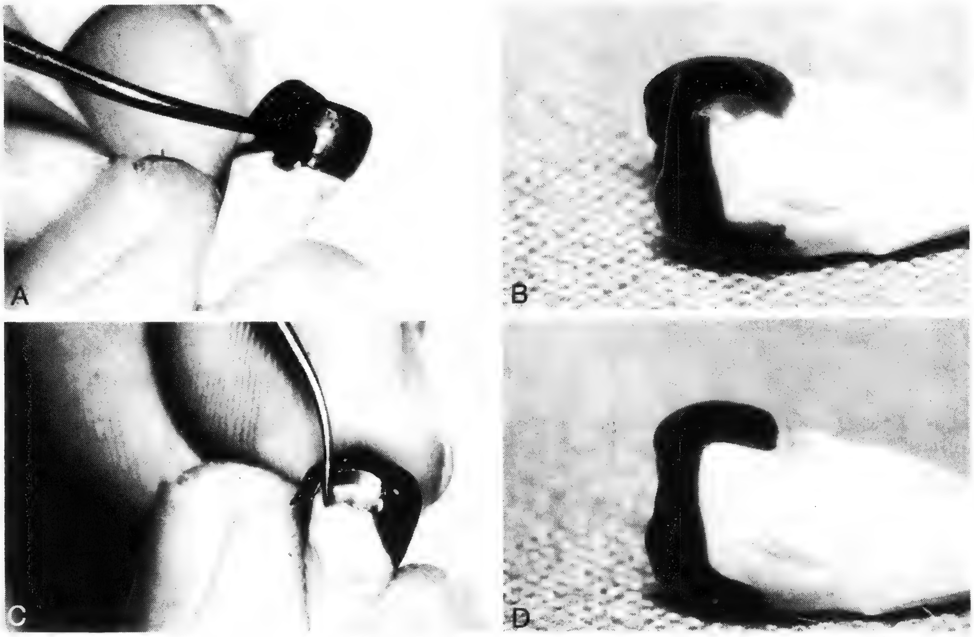


FIGURE 13–21 Marginal Readaptation

A, Marginal area of pattern being readapted.
B, Wax pattern with reflowed margin and showing excess cervical wax.
C, Excess cervical wax being removed with DPT number 6 instrument.
D, Reseated pattern showing good marginal adaptation

then reseated to reinspect the marginal adaptation (Fig. 13–21D). If any wax has fractured or has become visibly distorted, additional marginal adaptation must be performed. Once the pattern has passed the test of removal and reseating without a change in its quality of adaptation, it is ready to be invested.

POSTERIOR PARTIAL VENEER WAX PATTERNS

Cone waxing may be used to produce patterns for posterior partial veneer crowns. The lingual cones are usually easily placed, but the buccal cones may be quite short owing to limited occlusal space. However, the remaining steps are handled as previously discussed.

ANTERIOR PATTERN FABRICATION

The cone-waxing technique also can be used for anterior full-coverage wax patterns but does not lend itself to pinledge and anterior partial veneer patterns, since their form is largely determined by the morphology of the remaining tooth structure and by the occlusion. Cone waxing for anterior restorations is discussed in Chapter 22.

A pinledge wax pattern is unique in that plastic pins are placed into the pinholes of the die, and the wax pattern is formed around the pins. The bur used to prepare the pinholes must have the proper size relationship to the plastic pin used in the die. As discussed in Chapter 7, either tapered or parallel pinholes can be created in the tooth.

For tapered pins, the die is lubricated, and properly fitting plastic pins* are fully seated into the pinholes. The pins are shortened using a hot number 2 waxing instrument to sear through the plastic pin and leave about 0.5 mm of pin projecting above the prepared surface. A head is produced on the pin as the plastic is melted, which allows the wax to grasp the pin (Fig. 13–22A). Wax is picked up with the number 1 waxing instrument and made to flow around the pins and over the die surface. The wax should be slightly hotter than normal to allow complete flow around the head of the pins.

Removal of the pinledge pattern after marginal adaptation has been completed can be accomplished in different ways. One is to overbuild the lingual surface and, while the wax is still soft, stick the blade of an instrument such as the DPT number 6 into the extra bulk to produce a cavelike indentation. After the wax has become firm, the instrument is placed back into the indentation, and the pattern is pulled free from the die (Fig. 13–22B). Another removal technique includes a wax sprue attached to the pattern to form a handle for removing the pattern.

The wax pattern for a pinledge with parallel-walled pinholes is handled in the same manner, except that a different type of plastic pin is used. A parallel-sided plastic pin that is 0.075 to 0.10 mm (0.003 to 0.004 inch)

*Williams Plastic Pins, Williams Company, Buffalo, NY 14214.

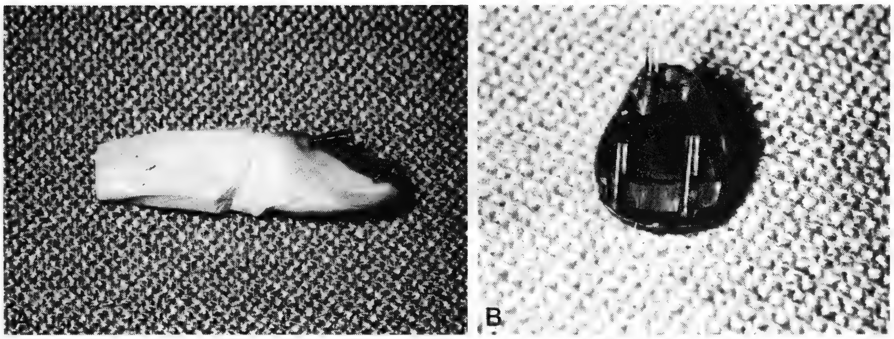


FIGURE 13–22 Pinledge Wax Pattern with Tapered Pinholes

A, Three tapered plastic pins seated on the die. The two incisal pins have been shortened, and a head has been produced by melting the plastic with a hot instrument.
B, Pinledge pattern removed from die.

smaller than the drill used to prepare the tooth is placed into the pinhole in the die. The plastic pin has to be smaller than the pinhole to avoid binding of the cast pin. A section of the plastic is shortened, and a head is created by melting the plastic as previously discussed (Fig. 13–23).

PONTIC WAX PATTERNS

All-Metal Sanitary Form

When there is restricted space in the edentulous area and porcelain is not required for esthetic reasons, an all-metal pontic is often indicated. The edentulous ridge is lubricated, and wax is applied directly to the working cast until gross cervical form is achieved with some excess wax present. After the wax has cooled, the pattern is removed from the cast and carved until the desired cervical form and axial contour are completed. The pattern is then returned to the cast for evaluation of the form and correction of any defects prior to completion of the occlusal surface (Fig. 13–24).

Metal-Ceramic Pontics

The formation of wax patterns for metal-ceramic pontics is discussed in Chapter 23.

Wax Pattern for a Reverse Pin Facing

A reverse pin facing is fabricated from a porcelain denture tooth. It is generally shaped so that the porcelain is adapted only to the facial aspect of the edentulous ridge, with the lingual ridge adaptation being completed in metal.

The wax pattern incorporates plastic pins that fit into holes, which are drilled into the back of the facing. Thus, metal retentive pins are formed as part of the cast backing. The pins used in the wax pattern are the same type as described with the pinledge wax pattern utilizing parallel-walled pinholes. The pins should also have the same undersized relationship to the carbide drill as described previously.

The lingual aspect of the facing is lubricated, and plastic pins of appropriate size are fully seated into the holes. A hot instrument is used to shorten the plastic pin and produce a head for retention in the pattern (Fig. 13–25A, B). Hot wax is then made to flow over the pins and bulk is established so that intact removal of the pattern from the facing can be verified. Wax should not be applied to the cervical portion of the lingual surface at this time because it may interfere with the subsequent ridge adaptation, which is completed on the working cast. Lubricant is then applied to the edentulous ridge on the working cast and the facing is positioned into the previously obtained facial index and attached with a small amount of sticky wax.

Hot wax is then added to the partially formed wax pattern and made to flow over the area of the edentulous ridge that is to contact the metal casting (Fig. 13–25C). When the wax cools, the pontic is removed and inspected to determine that wax has flowed smoothly over the edentulous ridge area and that no defects are present (Fig. 13–25D, E). Corrections are made by placing the pontic back into the facial index and making the wax reflow. The axial contour and occlusal portion of the wax pattern are then completed in the usual manner.

ATTACHING PONTICS AND RETAINERS FOR ONE-PIECE CASTINGS

An entire bridge can be cast in one piece. However, bridges that are cast in two or more pieces and then

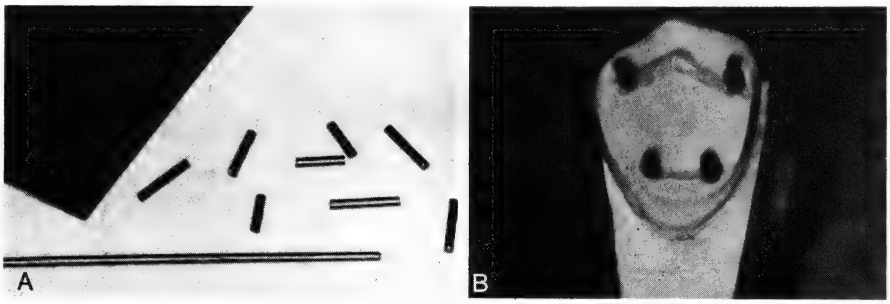


FIGURE 13–23 Pinledge Wax Pattern with Parallel-Walled Pinholes

A, Razor blade used to cut nylon pin material into short segments.
B, Shortened plastic pins seated into die.

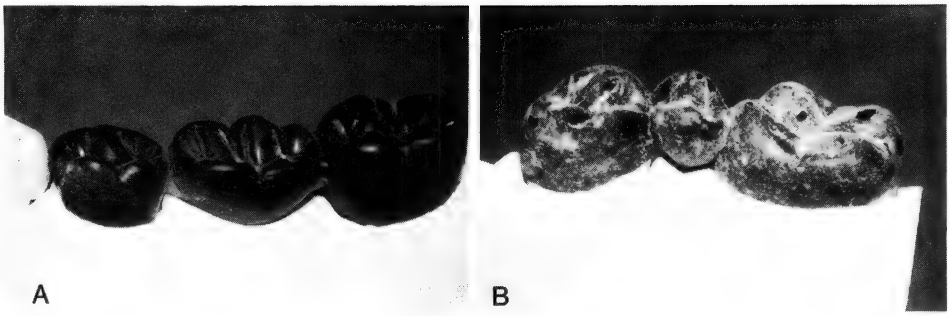


FIGURE 13–24

A, Pattern for all-metal pontic where occlusocervical space was limited.
B, Pattern for all-metal pontic with limited mesiodistal space.

connected by soldering are consistently more accurate than bridges cast in one piece.

Yet there are times when it is advantageous to connect a pontic pattern to an abutment pattern and cast the units together. As an example, a three-unit bridge can be completed from two sections with one solder joint, allowing easier assembly either from the cast or the mouth.

This procedure is not recommended for the neophyte because of the technical difficulties involved and because

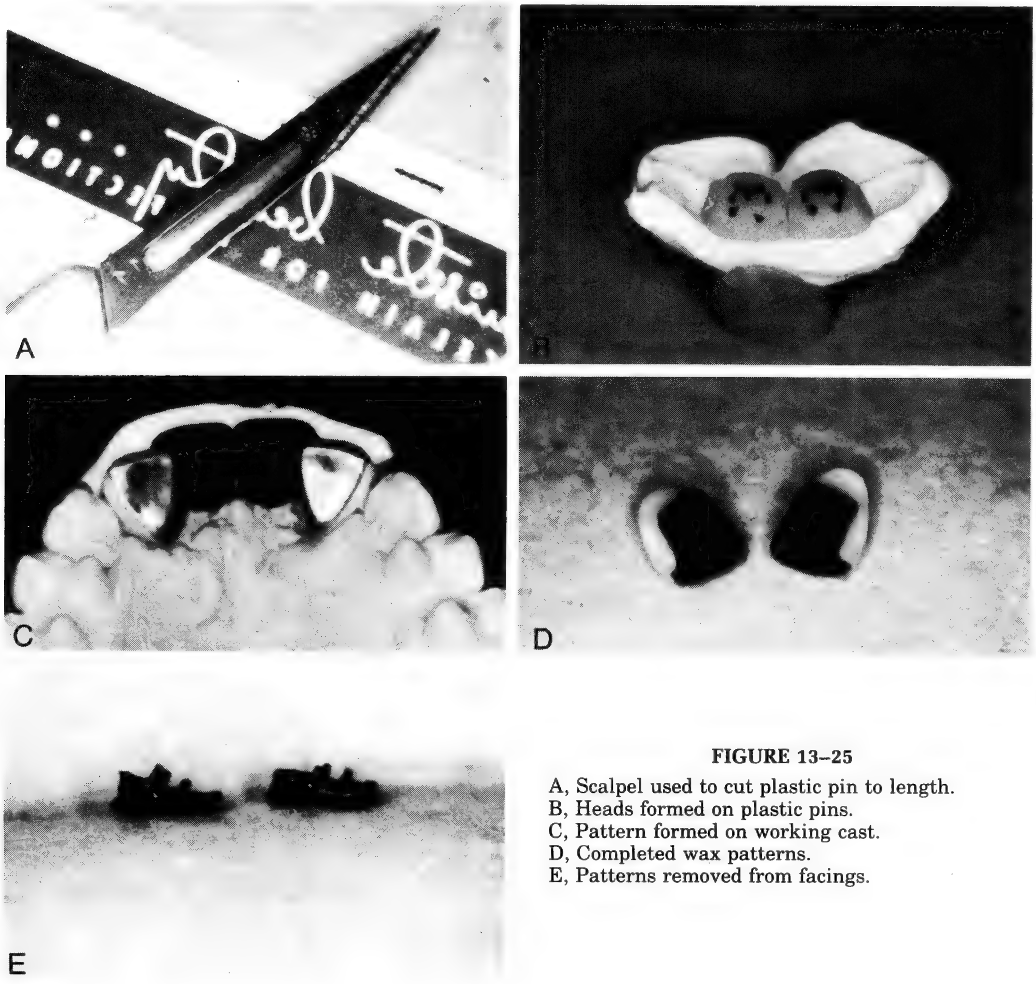


FIGURE 13–25

A, Scalpel used to cut plastic pin to length.
B, Heads formed on plastic pins.
C, Pattern formed on working cast.
D, Completed wax patterns.
E, Patterns removed from facings.

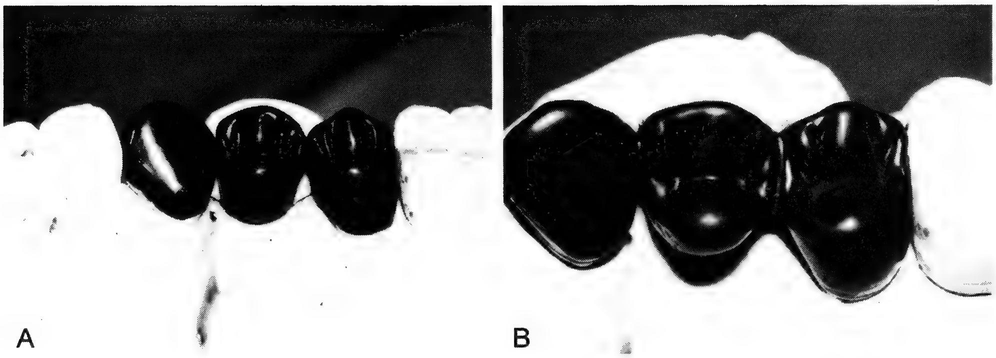


FIGURE 13–26

A, Pontic positioned in facial index.
B, Distal wax connector formed.

a casting failure results in both parts having to be remade. It is a process reserved for certain clinical situations and a technically experienced individual.

The completed abutment wax patterns are seated on the working cast, and the facial index is luted into position with sticky wax. The pontic is placed into the index and attached to it with sticky wax (Fig. 13–26A).

A joint or connector between the two parts is then formed in wax in the area in which the proximal contact is normally located. This is done by applying molten wax so that it flows around the contact area and produces the desired size and elliptic form (Fig. 13–26B). The wax should be hotter than normal to promote complete flowing, since it is sometimes difficult to make incompletely formed connectors reflow without disturbing adjacent contours. If too much wax is inadvertently added, the excess material must be carved away to prevent the connector from impinging upon the periodontally critical cervical embrasure. In some cases, when the cervical embrasure is not large enough to permit access for reflowing or carving, the parts must be separated and the connector reformed. Separation of the parts may be accomplished by using a piece of unwaxed floss to gently saw back and forth through the wax or by the use of a metal ribbon saw.

Once the connector form and size are correct, the wax is allowed to cool and stabilize for several minutes. The patterns are then ready for the attachment of sprue formers.

14

Investing

INTRODUCTION

An accurately fitting casting is the most important objective of the investing and casting process. The less exact the fit of the restoration, the wider is the band of the exposed luting cement, which often is referred to as the "cement line." The greater the amount of cement at the margin, the greater is the potential for microleakage and secondary caries owing to the dissolution of the cements commonly used. If the casting is well adapted, disintegration of the resulting thin layer of cement is not a significant problem.

Obtaining an accurate casting from the investing and casting process is predicated on compensating for the thermal shrinkage of the metal, which occurs as it cools in the investment mold. The exact figure for casting shrinkage is unknown. Published values range from 1.1 to 2.1 per cent. A value of 1.4 ± 0.2 per cent is considered a logical value for modern dental casting gold alloys.

Various methods are used to compensate for the thermal contraction of the alloy. These include (1) thermal expansion of the wax pattern, (2) setting expansion of the investment, (3) hygroscopic expansion of the investment, and (4) thermal expansion of the investment. Assuming that the wax pattern fits the die properly, the investment mold is enlarged via one or more of these mechanisms in order to adjust for the shrinkage of the alloy.

Another important objective of the investing and casting process is the production of a dense casting with a smooth surface. Internal porosity results in voids that weaken the casting. External porosity allows tarnish and corrosion to occur, posing difficulties to the patient in achieving effective plaque removal.

To obtain a dense high-quality casting requires a thorough knowledge of the casting alloy and its handling characteristics and meticulous attention to the technical details of the investing and casting process. Of particular importance is an understanding of the solidification process of molten alloy in the mold. The metal solidifies first in the thinner areas of the casting. Then solidification progresses throughout the thicker areas of the casting. As the casting solidifies and contracts, molten metal is fed to the casting through the sprue opening from the still molten button. This ensures a dense casting. The sprue then solidifies, followed in turn by the button. In this manner, ideally any porosity resulting from solidification shrinkage will be located in the sprue and button and not in the casting.

Although it is true that the perfect casting has never been made, dental casting procedures have progressed to a point at which failure, which has become the rare exception, usually can be traced to not following the basic principles associated with sound technique.

INVESTING

THE SPRUE FORMER

A sprue former is attached to the wax pattern after it has been readapted to the die and the margins have

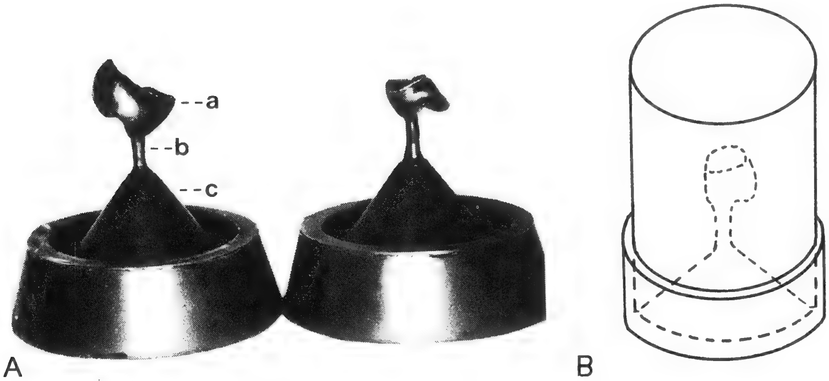


FIGURE 14–1

A, Wax patterns (a) attached to sprue formers, (b) which are attached to crucible formers (c).
B, Casting ring inserted into crucible former and encompassing pattern.

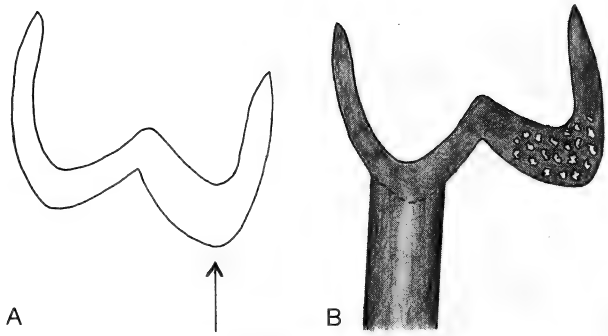


FIGURE 14–2
A, Proper location of sprue former on thickest area of wax pattern.
B, Porosity in thicker area of casting from sprue former attachment to thinner area.

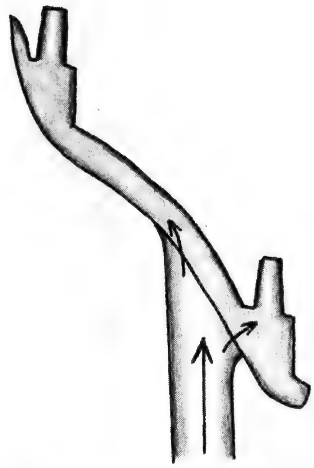


FIGURE 14–3 Sprue former attached to pinledge so molten alloy can flow toward pinholes.

been refined as discussed in Chapter 13 (Fig. 14–1A). The sprue former is then attached to a crucible former into which a casting ring can be inserted (Fig. 14–1B). The ring functions to contain the investment as it hardens around the wax pattern.

The function of a sprue former is to provide a channel or sprue into the investment mold through which molten metal can travel and reach the area in which the wax pattern was located.

Wax is the most common material for a sprue former because of its versatility in forming the different shapes, sizes, and lengths needed to make dental castings. Metal and plastic sprue formers are also available.

Location

The sprue former should be attached to the thickest portion of the wax pattern (Fig. 14–2A). Placement on a thin area of the pattern can result in porosity in the thicker areas of the casting (Fig. 14–2B). Since the thin area of the casting solidifies first, the still molten sprue and button are prevented from supplying additional metal to the thicker areas of the casting. The result is "shrinkage porosity" in the bulky portions of the casting.

The sprue former should not be located where it can obliterate centric occlusal contacts or require considerable adjustment of the casting for eccentric mandibular movements. Maxillary buccal and mandibular lingual cusps (nonworking cusps) are generally used as points of sprue former attachment for full veneer crown patterns. On partial veneer crown patterns, one of the cusps that completely encompasses the preparation should be used as the attachment location, rather than attaching the sprue former to one of the cusp tips which is close to the margin of the wax pattern. Placing a sprue former close to a margin may cause pattern deformation as well as restrict the flow of the molten metal into the mold.

The sprue former for pinledge wax patterns is generally located toward the incisal aspect of the lingual surface and angled so that the molten alloy can readily flow into the pinholes (Fig. 14–3).

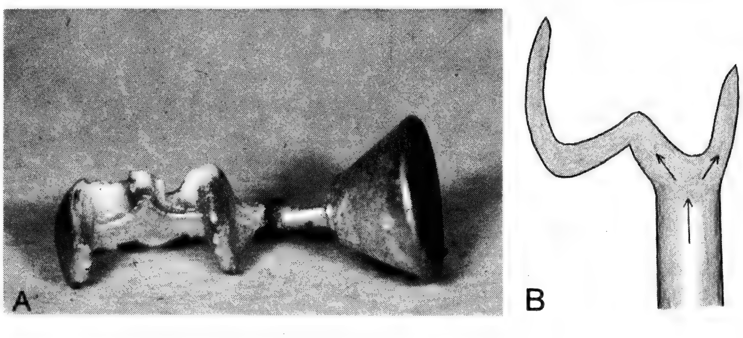
Angulation

The sprue former should not be placed perpendicular to a flat portion of the pattern in order to lessen the chance of excessive turbulence during casting and the subsequent formation of porosity (Fig. 14–4A). It is best to attach the sprue former so the molten alloy is divided by the underlying form of the prepared tooth as reproduced in the investment (Fig. 14–4B).

Size

A sprue former that is thicker than the thickest portion of the wax pattern should be used to permit solidification of the metal in the casting prior to the sprue and button (Fig. 14–5A). If a thin sprue former is

FIGURE 14–4
A, Sprue former position caused gold turbulence and resultant porosity and broken sprue.
B, Sprue former angled so alloy is readily dispersed upon entering mold.



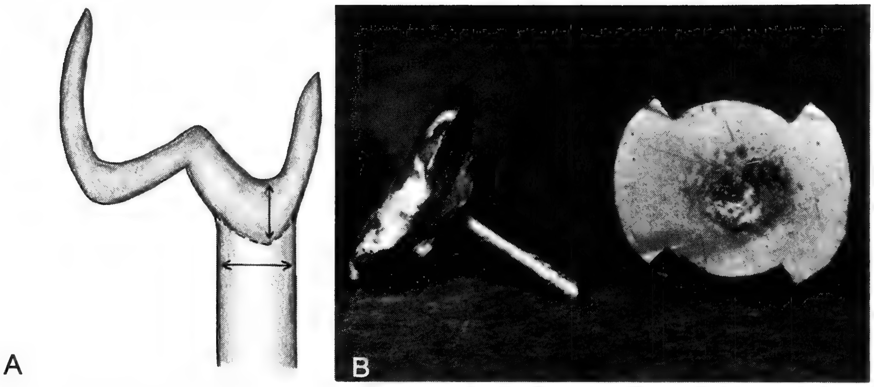


FIGURE 14–5
A, Sprue former should be larger in diameter than the thickest part of the wax pattern.
B, Shrinkage porosity resulting from use of a thin sprue former.

used, the sprue may solidify first and cause shrinkage porosity in the restoration (Fig. 14–5B). In most instances, a ten-gauge sprue former is adequate. Small wax patterns may require the use of smaller sprue formers to prevent distortion of the pattern when the sprue former is attached. With extremely thick wax patterns, a larger size (eight-gauge) may be required.

Some wax patterns are so thick that it becomes extremely difficult to obtain a dense nonporous casting. Whenever possible, these situations should be avoided by building up the tooth with some restorative material prior to completing the tooth preparation. When this is not possible, the use of a "chill set" can aid in obtaining a dense casting. A chill set is a length of thin-gauge sprue former wax (generally 18-gauge), which is attached to the wax pattern directly opposite the larger sprue former and which terminates within the investment but close to its periphery (Fig. 14–6). It is theorized that when a chill set is used, the molten alloy entering the mold goes directly into the chill set, which begins to solidify first because it is small and close to the cooler external surface of the mold. This then induces solidification in the main body of the casting and causes it to freeze before the sprue.

Length

The length of a sprue former generally should not exceed 5 mm or be less than 2 mm, since both excessively long or excessively short sprue formers present problems in obtaining high-quality castings (Fig. 14–7).

A very short sprue former can produce porosity in the area of the casting to which the sprue is attached, since the button, which should solidify last and therefore not be as dense, is too close to the casting.

A short sprue former can also place the mold space in the investment so far from the end of the casting ring that gases that remain from the wax burnout cannot escape easily through the investment. This may result in back-pressure porosity. For this reason, the portion of the wax pattern farthest away from the sprue former should be located about 6 mm from the open end of the ring. With the commonly used conical crucible formers, a sprue former 5 mm long usually places the pattern in reasonable proximity to the end of the ring.

With a very long sprue former, it is more likely that the first portion to solidify will be the sprue, with resulting shrinkage porosity in the casting.

A reservoir can be used when the length of the sprue former is such that it places the button too far from the casting. A reservoir is formed by a mass of wax or plastic, generally spherical in form, which is attached to the sprue former relatively close to the point of attachment of the wax pattern (Fig. 14–8). When the molten alloy is cast into the investment, the metal in the reservoir helps prevent shrinkage porosity by supplying molten metal to the casting as it solidifies. Plastic sprue formers are available that have preformed reservoirs attached in the appropriate location.

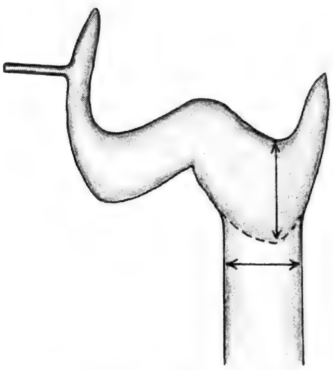


FIGURE 14–6 An 18-gauge chill set attached to thick wax pattern to induce solidification.

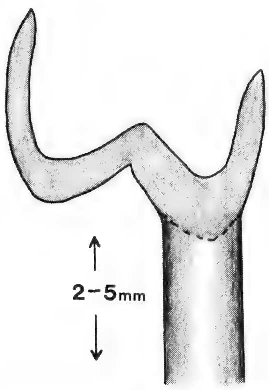


FIGURE 14–7 Recommended range for length of sprue former.

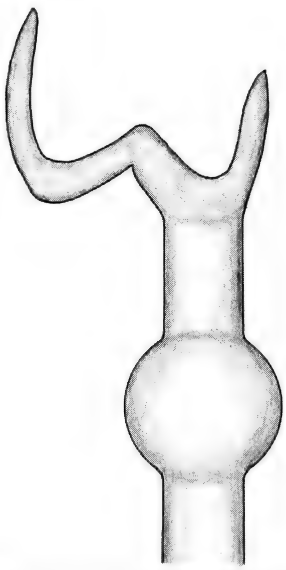


FIGURE 14–8 Spherical reservoir attached to long sprue former.

Shape

The sprue former should be as straight as possible in order to lessen the chance of excessive turbulence as the alloy enters the mold. Such turbulence increases porosity.

Number

The use of two sprue formers may be advantageous for wax patterns that possess two bulky areas separated by a thinner area (Fig. 14–9). A single sprue former attached to only one of the bulky areas increases the potential for shrinkage porosity, since early solidification of the thin areas prevents further supply of molten alloy to the other bulky area.

Sprue Former and Wax Pattern Connection

The attachment of the sprue former to the wax pattern should be such that the transition in form from sprue former to pattern is smooth and does not possess pits or irregularities into which investment can flow (Fig. 14–10A,B). Irregularities produce small tags of investment that can be broken off and carried into the mold by the molten alloy, thus producing defects in the casting (Fig. 14–10C). Irregularities in the sprue may also cause turbulence in the flow of molten alloy entering the mold.

After the sprue former has been attached, the wax pattern should once again be removed and reseated to ensure that no marginal distortion or fracture occurs (Fig. 14–11).

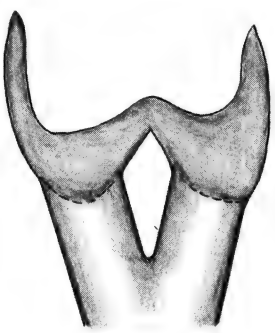
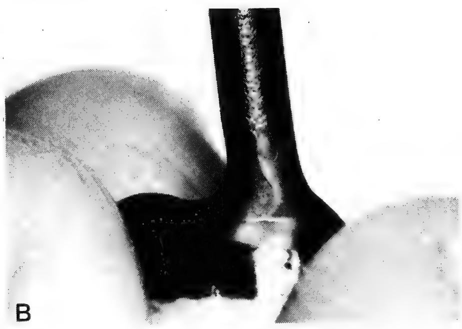
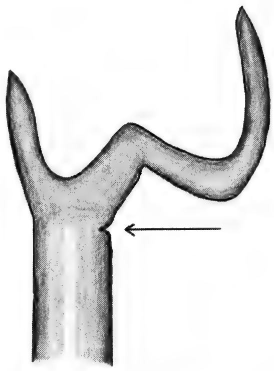


FIGURE 14–9 Use of two sprue formers because of two thick areas separated by a thinner area.

A



B



C

FIGURE 14–10

A, Sprue former pressed into contact and adhering to pattern.
B, Smooth transition developed between sprue former and pattern by addition of wax.
C, Irregularity present into which investment can flow and possibly fracture when molten alloy enters the mold.

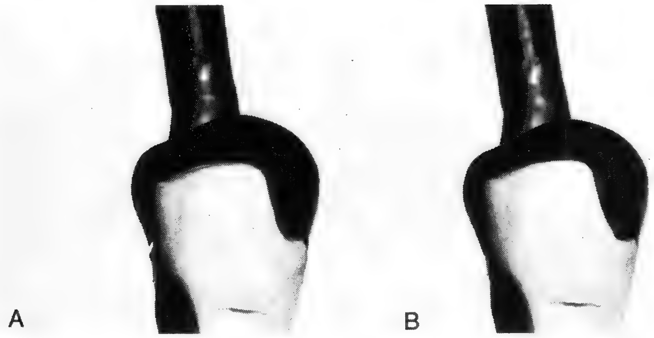


FIGURE 14–11
A, Pattern partially removed.
B, Pattern reseated to verify that removal caused no marginal distortion.

Sprue Formers for Multiple Units

The casting of joined multiple units of a fixed partial denture is sometimes done in order to simplify future steps in the laboratory or clinical procedures. An example is casting a pontic attached to one of the retainers in order to facilitate completion of the assembly of the prosthesis by soldering (Fig. 14–12).

Sprue formers are attached to the connected units and gently curved toward each other so that they can be joined together with molten wax while the assembly is still on the working cast. After the wax has cooled and stabilized, the unit is removed from the working cast so the pattern can be readapted to the die. Marginal refinement is accomplished in the usual manner, except that proximal access is restricted by the attached pontic, often requiring the use of a cervical approach (Fig. 14–13). Careful handling of the united parts is mandatory so that relationships are not distorted during margination.

Use of a Transverse Bar

To cast multiple units, some authorities advocate the use of a transverse or runner bar that feeds molten alloy to the individual units (Fig. 14–14). The alloy enters the mold through large sprue formers (often 8-gauge), into the horizontally positioned transverse bar (often 10-gauge), and finally into the sprue formers to the individual units (often 12-gauge).

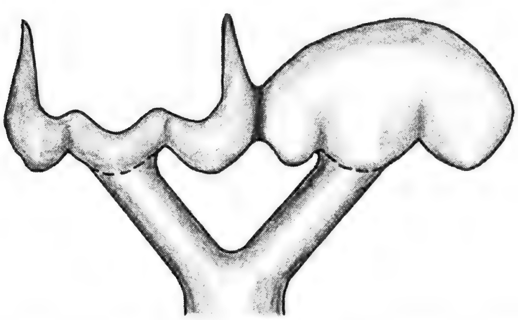


FIGURE 14–12 Pontic and retainer with sprue formers attached so they can be cast as one piece.

The Crucible Former

The crucible former forms the conical depression in the end of the investment mold that guides the molten alloy into the channel left by the sprue former and on into the void in which the wax pattern was located. It may be made of rubber, metal, or plastic.

The crucible former should be clean and free of investment or foreign material prior to attachment of the sprue former. It is advantageous to coat the surface with a thin layer of petroleum jelly to prevent adherence of investment. A rough investment surface is often created when a nonlubricated crucible former is separated from the hardened investment. This allows the molten alloy to pick up small particles of investment as it enters the mold, thereby producing inclusions or voids in the casting.

The wax pattern and attached sprue former are removed from the die, with special care being taken to avoid distortion of the wax. Molten sticky wax is applied to the apex of the cone-shaped portion of the crucible former, and the end of the sprue former is placed into the sticky wax and held there until the wax hardens. The area of attachment should be smooth and without irregularities, which create projections of investment that may be loosened and carried into the mold by the molten alloy.

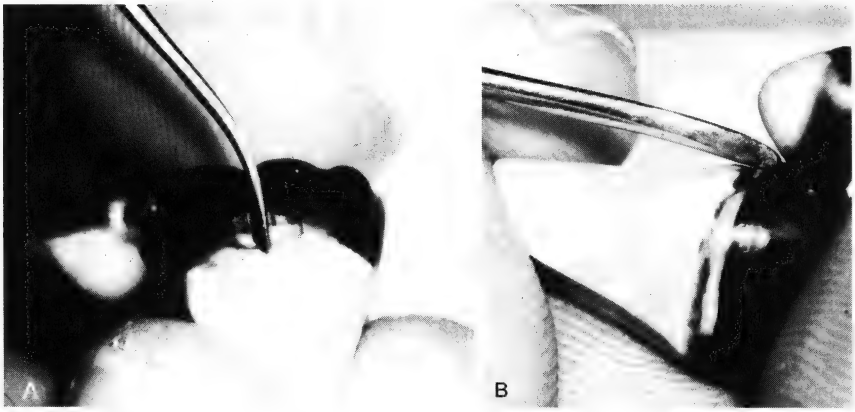
Casting Rings and Liners

A solid metal ring is generally used to confine the fluid investment around the wax pattern while the investment sets and to allow the hardened investment to be handled safely during burnout and casting. If the investment sets in direct contact with the metal ring, there will be a restriction of the setting expansion of the investment. This leads to an undersized casting, since setting expansion must provide part of the compensation for the solidification shrinkage of the alloy.

The usual method of overcoming this problem is to line the metal ring with a material that does not restrict the setting expansion of the investment (Fig. 14–15). The liner should be moistened to prevent it from absorbing investment liquid and altering the water-powder ratio.

A thin sheet of asbestos is considered to be the ideal type of liner material and has been used successfully to fabricate well-fitting castings for many years. However, in recent years, the carcinogenic potential of asbestos

FIGURE 14–13
A, Marginal refinement being started facially.
B, Proximal marginal refinement.



has caused concern. Asbestos has become difficult, if not impossible, to obtain through dental suppliers and can be located only through commercial sources. However, the harmful microsized asbestos particles are well bound in the thin asbestos sheets commonly used as ring liners, and there is no scientific evidence that there is any health danger to dental personnel when sheet asbestos is used with care.

Owing to the difficulty of obtaining asbestos, two types of substitutes have become available. One is paperlike and made of a cellulose material that has water sorption and handling properties similar to those of asbestos. However, this material burns out when the investment is placed in a furnace and heated to eliminate the wax. The other substitute is a ceramic material made of a silica-alumina compound that is refractory like asbestos but that has very low water sorption. A wetting agent is used with this type of liner, since the use of the dry ceramic liner can produce inconsistent results in casting fit.

When properly handled, both of these asbestos substitutes can be used in the fabrication of well-fitting castings.

Pattern Orientation in the Casting Ring

Whenever possible the wax pattern is centered in the casting ring, where the expansion of the investment is most uniform.

When a centrifugal casting machine is to be used, a notch or arrow should be ground on the external surface of the casting ring using a separating disc so that the location of the trailing edge of the wax pattern can be controlled and identified after investing (Fig. 14–16). This is important, because when the casting machine is released and the molten alloy enters the investment, it travels first toward the trailing edge of the investment mold. Orienting the wax pattern with the critical margins and thinner areas located toward the trailing edge of the ring ensures that these areas are cast first and completely and that solidification can progress in an orderly manner throughout the casting. Marking the ring to identify the trailing edge allows accurate placement of the ring in the casting machine (Fig. 14–17).

Investments

Dental casting investments are composed of a refractory material, a binder, and modifiers such as reducing agents, accelerators, and retarders. Some form of silica is generally used as the refractory agent to produce thermal expansion of the mold.

The binder functions to hold the ingredients together and allows the formation of a reasonably strong mold into which molten metal can be cast. Dental investments may be classified in a number of ways. One is by the type of binder. For example, *phosphate-bonded* invest-

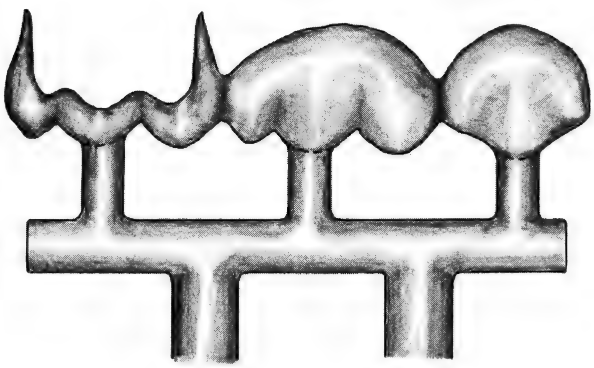


FIGURE 14–14 Transverse bar sprue former assembly attached to retainer pattern and two pontics.

FIGURE 14–15 Metal casting ring lined with asbestos. Note the sticky wax used to hold the liner in position.

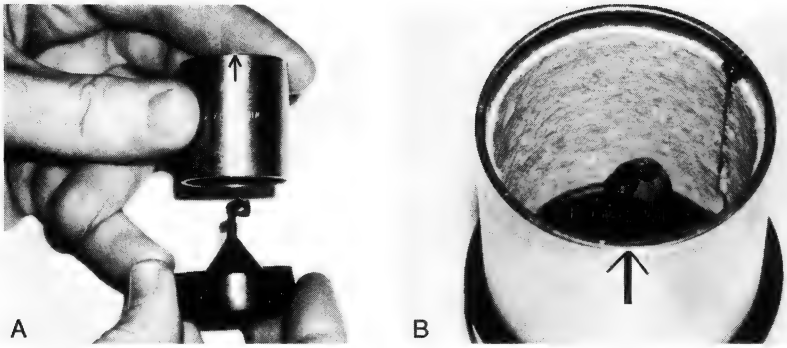


FIGURE 14–16

A, The critical margins and thinner areas of the pattern are oriented in the ring so they are 90 degrees to the right of the arrow and will be toward the trailing edge during casting.
B, Casting ring seated over pattern. Note the orientation of the pattern relative to the arrow on the ring.

ments utilize a phosphate compound as the binder. These investments can be used to cast conventional noble metal alloys but are not discussed here, since they are required for casting of metal-ceramic restorations (see Chapter 22). *Silica-bonded* investments are not discussed, since they are used principally in casting base metal alloy frameworks for removable partial dentures. The traditional investments used for the noble metal alloys use a form of gypsum as a binder and are referred to as *gypsum-bonded.* Dental stone (alpha-hemihydrate) is generally used as the binder.

Investment Expansion

Thermal Expansion

Thermal expansion of the refractory material, when it is heated, provides a major portion of the expansion of the mold. The refractory material used in dental investments is either quartz or cristobalite; these are different physical forms of silica. These two allotropic forms undergo a transition in particle size as they are heated. They differ in the amount of thermal expansion reached during this transition and the temperature range at which it occurs.

Characteristic thermal expansion curves for investments containing quartz and cristobalite are shown in Figure 14–18. It can be seen that the ultimate thermal expansion of the cristobalite investment (Curve A) is greater than that of the quartz investment (Curve B). In addition, the maximal expansion of cristobalite takes place over the rather narrow temperature range of 232° C (450° F) to 371° C (700° F), then levels off to a comparatively flat plateau, while the quartz investment continues to expand relatively uniformly until about 566° C (1050° F).

If investment is permitted to cool, the contraction follows essentially the same curve, and so the plateau of a cristobalite investment affords quite a bit of latitude during the casting procedure. For instance, if the casting ring is taken out of the furnace at 649° C (1200° F) and

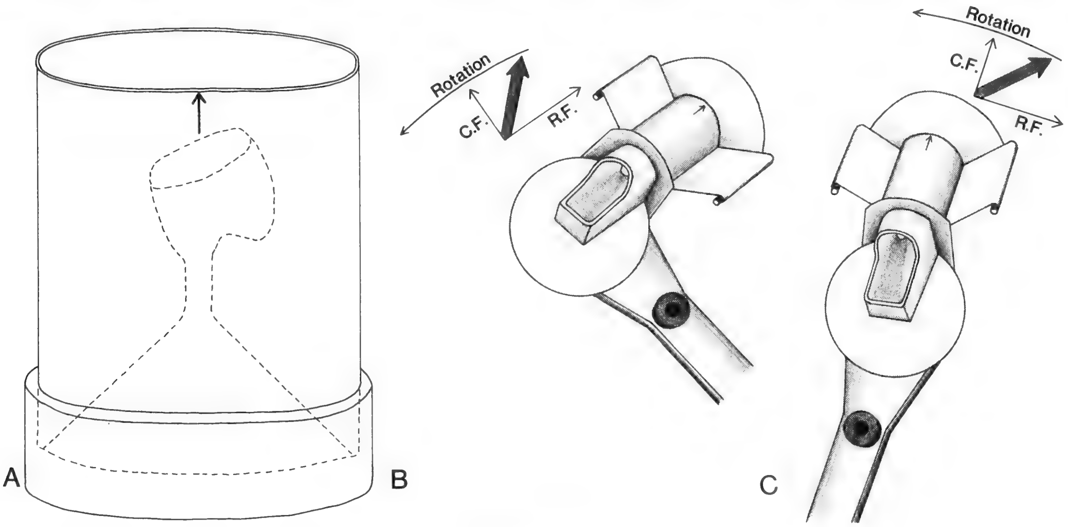


FIGURE 14–17

A, Orientation of pattern inside ring relative to arrow.
B, Casting ring in broken arm centrifugal casting machine as the machine is released. Casting machine begins rotating counterclockwise, as indicated by rotation arrow. As molten alloy enters the mold it is controlled by two forces. Centrifugal force (C.F.) attempts to push the alloy laterally in a direction parallel with the long axis of the rotating arm. The rotational force (R.F.) attempts to force the alloy to the right. The resultant force or the direction in which the alloy enters the mold is toward the trailing edge, as indicated by the large arrow.
C, Shortly after the casting machine begins to rotate, the broken arm straightens out and maintains this orientation. Note that the pattern was oriented so the critical margins are toward the trailing edge.

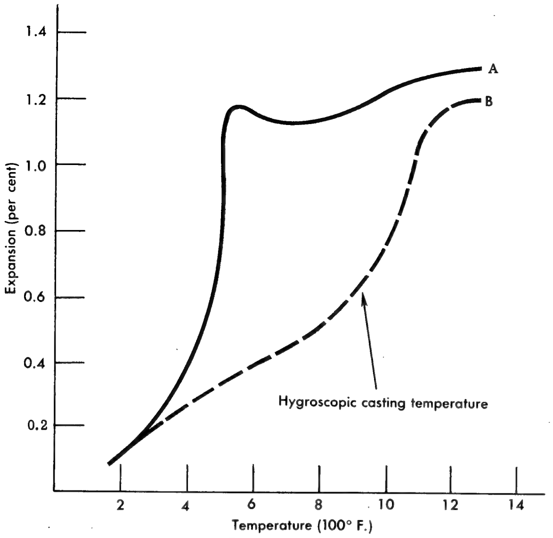


FIGURE 14–18 Thermal expansion of a typical cristobalite (A) investment and a quartz (B) investment. The amount of expansion that occurs in a quartz investment at the wax burnout temperature when the hygroscopic investing technique is used is also noted. (After R. Neiman, Whip-Mix Corp.)

several minutes are taken to melt the alloy and make the casting, the temperature drop in the investment does not cause a significant contraction in the mold. Conversely, when a quartz investment is removed from the furnace, cooling contraction is faster and more pronounced.

Setting Expansion

The mold is also enlarged by expansion of the investment as it hardens. However, the amount of expansion obtained on setting is considerably less than is the thermal expansion. The normal *unrestricted* setting expansion is approximately 0.3 per cent (Curve A, Fig. 14–19), but this amount of expansion may not take place because the investment is confined and restricted somewhat by the metal ring that is used to contain the pattern and the investment. The setting expansion that actually does contribute to an enlargement of the mold is called the *effective* setting expansion.

Part of the effective setting expansion is the result of thermal expansion of the wax pattern, which stems from the heat liberated during setting of the investment. In addition, as the investment hardens and expands, it eventually gains enough strength so that it can effect a movement in the wax pattern.

The configuration of the individual pattern has some influence on the amount of effective expansion that occurs. If the walls are thin, the expansion is greater than if the walls are thick. The investment can move the thinner walls outward more easily; moreover, the proximal walls of a three surface inlay pattern may be displaced with less force than those of a full veneer crown that has continuous walls that offer more resistance to the expansion of the investment. Thus, to achieve the optimal casting fit for certain types of patterns, alterations in the thermal or setting expansion may be required.

Hygroscopic Expansion

Hygroscopic expansion is an increased setting expansion brought about by the addition of water to the mixed investment after it has been placed in the casting ring. The hygroscopic expansion investing technique evolved because it was believed that if wax elimination were carried out at a temperature of approximately 677° C (1250° F), the gypsum in the investment would break down and the surface of the resultant casting would be rough. If the wax burnout was made at a lower temperature, such as 482° C (900° F), then the casting would have a smoother surface. There is no evidence that a mold heated to 482° C (900° F) yields a smoother casting than one that has been rightly heated to 677° C (1250° F). Nevertheless, this theory has led to the development of the modern hygroscopic investing procedures.

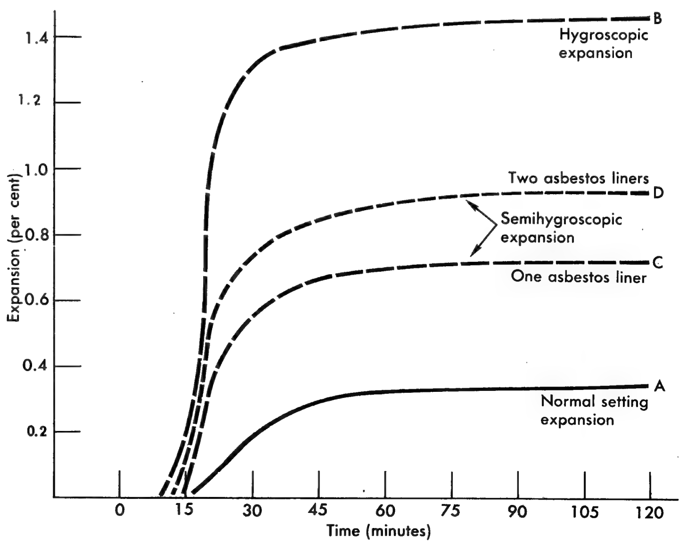


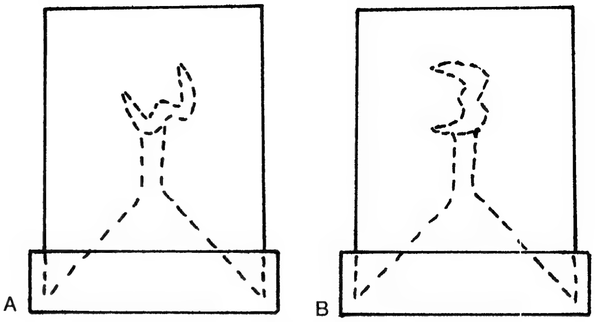
FIGURE 14–19 The normal setting (A) and hygroscopic (B) expansion of an investment are compared with the somewhat restricted expansion that occurs in a metal casting ring, which is lined with one (C) and two (D) asbestos liners. (After R. Neiman, Whip-Mix Corp.)

Curve B in Figure 14–18 shows that if a casting is made at a burnout temperature of 482° C (900° F), the full benefit of the thermal expansion of a quartz investment is not realized. This temperature is at the midpoint of the thermal expansion curve. By casting at the lower temperature, the thermal expansion that would occur between 482° C (900° F) and 649° C (1200° F) is sacrificed.

To secure the additional expansion necessary to compensate for the loss in thermal expansion, hygroscopic expansion techniques were developed. The most common method is to expose the investment to water by completely submerging the ring, immediately after investing, in a 38° C (100° F) water bath for approximately 30 minutes. A noteworthy amount of expansion takes place under such conditions (Curve B, Fig. 14–19).*

Another way to provide hygroscopic expansion is to add a limited amount of water to the setting investment. This is usually referred to as the "controlled water-added" technique. The degree of hygroscopic expansion is regulated to some extent by the amount of water that is added to the surface of the setting investment.

Whatever the investing technique, since the metal ring is ordinarily lined with a layer of wet asbestos or other resilient material, semihygroscopic expansion invariably occurs. The water in the liner causes a hygroscopic expansion of the investment in the area in which it is in contact with the wet liner. The additional expansion induced by one asbestos liner is shown in Curve C in Figure 14–19; with two liners there is an even greater semihygroscopic expansion, as shown in Curve D in Figure 14–19.



A B

FIGURE 14–20

A, Pattern orientation allows ring to restrict investment expansion.
B, Less restriction of investment expansion occurs along the long axis of the casting ring, and this pattern orientation allows more expansion to occur.

Controlling Investment Expansion

Equally satisfactory castings can be made by a number of techniques that employ thermal, setting, and hygroscopic expansion of the investment to enlarge the mold and compensate for the contraction of the gold alloy. Also, most castings can be made to an accurate fit using one level of expansion, at least at the magnitude provided by several of the popular commercial investments (Luster Cast,† Novocast‡ and Beauty-cast‡). There may be a few instances in which a casting that fits tighter may be sought or, conversely, in which a little more expansion is needed. Some latitude in expansion can be gained by altering certain of the variables found in the investing procedure. Decreasing the powder-water ratio reduces the setting expansion slightly, and vice versa. That is, if 50 grams of investment is used with 17 ml of water to produce an average degree of setting expansion, the use of 18 ml of water would decrease expansion and 16 ml would increase expansion. Such adjustment should be done with discretion, since undue deviation from the suggested ratio may deleteriously affect the strength of the investment and the character of the mold surface.

Keeping in mind that the most uniform investment expansion occurs when the pattern is located in the center of the ring, it is possible to alter the pattern orientation in the casting ring and achieve certain changes in expansion. If a sprue former is attached to the occlusal surface in the manner previously described, the effective setting expansion is reduced by the confining action of the ring (Fig. 14–20A). Greater expansion can be achieved, if needed, by attaching the sprue former so that the pattern is oriented in the direction of the open ends of the ring (Fig. 14–20B).

Short and converging retentive walls theoretically necessitate less compensation. There is little friction in the seating of such a crown, inasmuch as the casting does not touch the axial walls until it is almost in place, and the configuration of the pattern may influence the amount of effective setting or hygroscopic expansion. A full cast crown, particularly if the walls are long and parallel, generally calls for more investment expansion than a partial-coverage restoration.

The degree of expansion required for each type of preparation is learned through experience, and the technique is changed accordingly to increase or decrease the compensation.

It must be remembered that stability in a seated casting is mandatory to resist all forces that cause motion and, to a lesser degree, movement directed opposite to the path of insertion. The casting should fit closely on the prepared tooth, but it should seat completely with finger pressure.

As previously discussed, another method by which the dimensions of the mold may be altered is by the use of a resilient liner to permit more freedom in the expansion of the investment—freedom that otherwise would be restricted by the ring. In addition, the compressibility of the liner assists in offsetting the contraction of the more rapidly cooling ring after it has been removed from the furnace and while the gold alloy is being melted. Also, if a wet liner is used, the water in the liner affords some hygroscopic expansion (Fig. 14–19).

The distance between the end of the pattern and the unlined portion of the ring has been found to affect significantly the size of castings. Both the pattern and the lining must have a specific position in the ring to eliminate this variable. It is recommended that the pattern be placed at a constant distance of 6 mm from the open end of the ring (Fig. 14–21).

When expansion must be maximal, a liner flush with

*The reader is referred to accepted texts in the science of dental materials for a discussion of the theory of hygroscopic expansion.
†Kerr Manufacturing Company, Romulus, MI.
‡Whip-Mix Corporation, Louisville, KY 40217.

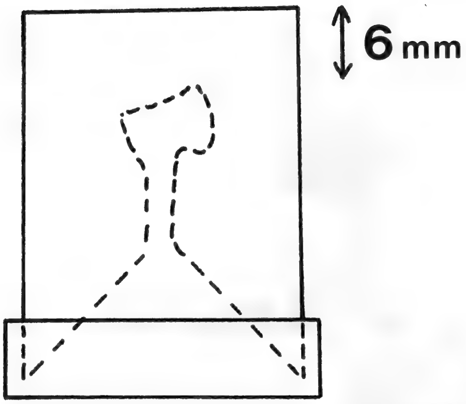


FIGURE 14–21 Pattern located so margins are 6 mm from end of ring.

the open end (the end opposite from the crucible former) of the ring should be used. A liner that is 3 or 6 mm short of the open end of the ring results in a somewhat smaller casting; the greater the unlined portion of the ring, the greater is the restrictive effect. The distance by which the liner is short should be carefully controlled, and the liner should be attached firmly to the ring by wax to prevent it from "riding up" during the investing procedure and inadvertently modifying the size of the casting. Increasing the number of liners provides additional expansion.

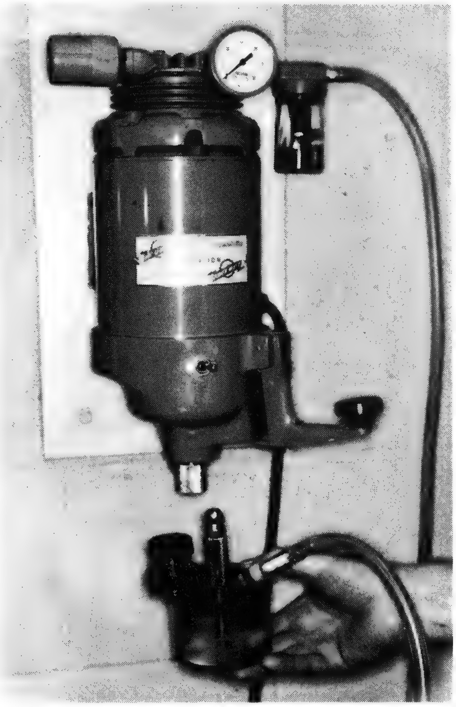


FIGURE 14–22 The Whip-Mix combination Vac-U-Vestor Power Mixer. It is shown here with the spatulator for vacuum investing.

Investing Procedures

Whether the pattern is to be invested by hand or by vacuum equipment, strict adherence to the water-powder ratio is a must. Deviations from the recommended ratio have an affect not only on the setting and thermal expansion, but also—and of more consequence—on the surface smoothness of the casting. When the mix is too thick, the investment flows sluggishly onto the surface of the pattern and air bubbles can be trapped, particularly in sharp corners of the pattern and occlusal grooves and fossae. A thin mix has less strength, increasing the possibility of fracture, particularly at the margins, during burnout or casting. Excessively thin mixes can also produce a generally rough casting surface.

Vacuum Investing Technique

Castings free of nodules can be secured routinely by either hand or vacuum investing, but if astutely handled, vacuum investing is certainly more nearly foolproof. With this method, reproduction of minute marginal detail is sharp and a smooth casting surface is achieved.

The most satisfactory type of vacuum investing equipment is one in which both the mixing and the investing are completed under vacuum (Fig. 14–22).

The mixing bowl, spatulator, and vacuum line must be free of investment, and the pump should be activated (with the mixing bowl, spatulator, stainless steel casting ring, and rubber crucible former in place) to make sure that the vacuum measures up to 26 to 28 inches of mercury.

The casting ring is lined with asbestos or an asbestos substitute of proper width and moistened with either water or a wetting agent, depending on the type of liner being used (Fig. 14–23A). The sprue former and wax pattern are attached to a clean lubricated rubber crucible former as previously described. The pattern is cleansed using a wax pattern cleaner and, if desired, painted with a very small quantity of wetting agent (Fig. 14–23B). A wetting agent decreases the likelihood of trapping of air bubbles on the surface of the pattern, which would produce nodules on the casting. More than a very light coat causes surface flaws on the casting; hence, any excess wetting agent should be taken up with a dry brush or a gentle stream of air. Vibration should be avoided when a wetting agent has been used, because the liquid tends to flow irregularly and to foam. The crucible former is then placed over the casting ring (Fig. 14–23C), which is seated into the hole in the lid of the spatulator (Fig. 14–23D).

The required armamentarium for vacuum investing includes the mechanical spatulator, a hand spatula, the investment, and the correct amount of liquid (Fig. 14–24A).

The inner surface of the mixing bowl is wetted with water and shaken several times to eliminate any excess (Fig. 14–24B). This step prevents the bowl from absorbing liquid from the mixed investment and altering the water-powder ratio and standardizes multiple investing procedures made in succession with the same equipment. A correctly measured amount of room-temperature water followed by the proper amount of investment powder are placed in the bowl and hand mixed with a

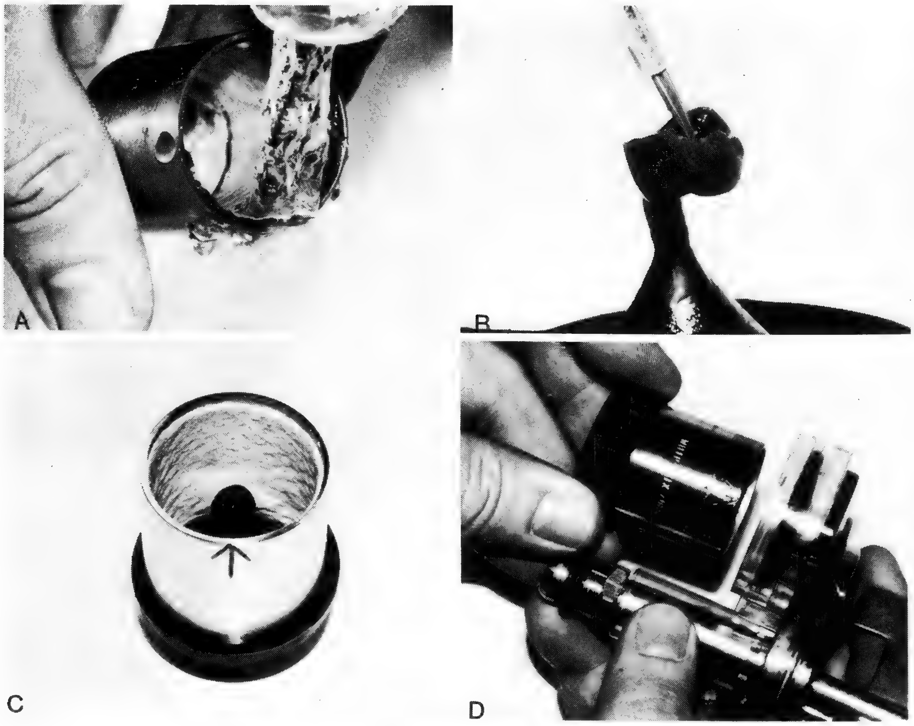


FIGURE 14–23

A, Ring liner moistened with water.
B, Wetting agent applied to wax pattern.
C, Ring seated into crucible former.
D, Ring aligned so it can be seated into lid of vacuum spatulator.

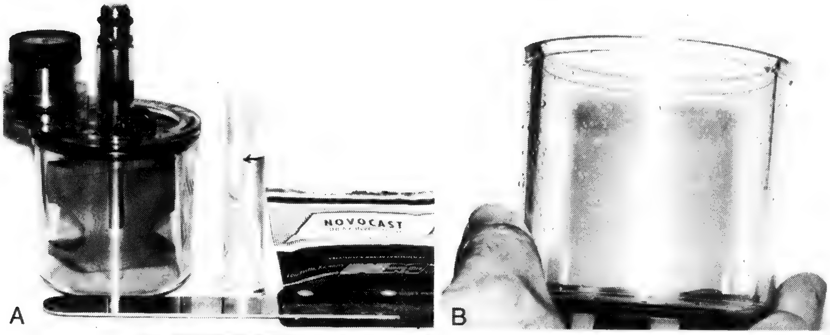


FIGURE 14–24

A, The vacuum investing armamentarium.
B, Moistened bowl shaken to remove excess water.
C, Investment powder being hand mixed with water.

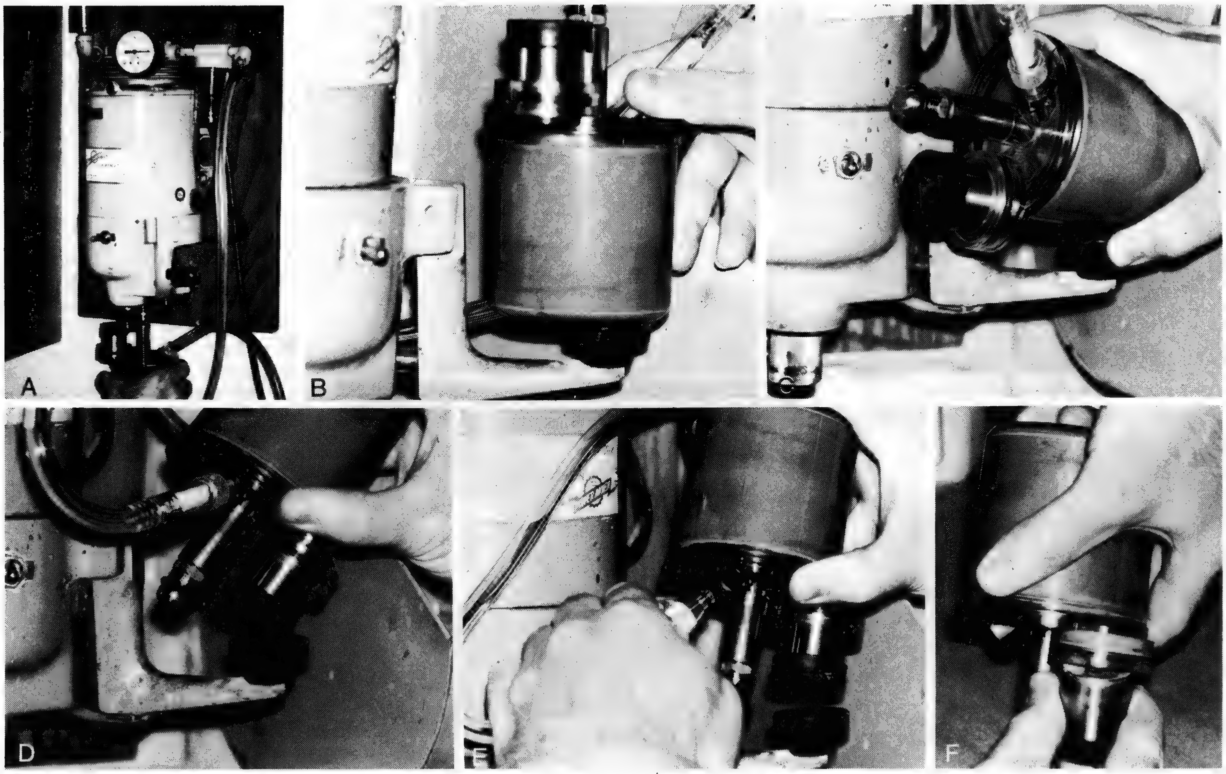


FIGURE 14–25

A, Investment being vacuum mixed.
B, Bowl placed on vibrating rubber covered pad.
C, Spatulator partially inverted.
D, Spatulator completely inverted.
E, Vacuum hose disconnected.
F, Ring separated from spatulator lid.
G, Ring vibrated lightly to smooth out investment surface.

metal spatula until all investment particles have been incorporated into the water (Fig. 14–24C).

The mechanical spatulator lid with casting ring attached is placed in the bowl, the vacuum line is connected, and the investment is mixed under vacuum for 15 to 20 seconds (Fig. 14–25A). While the vacuum is still in use, the bowl is slowly tipped upside down as the investment is vibrated to cause it to flow from the mixing bowl into the ring (Fig. 14–25B, C, D). If the casting ring is rapidly carried to a vertical position, bubbles may be formed on the surface of the wax pattern adjacent to the sprue former.

When the ring is filled with investment, and while the machine is still running, the vacuum tubing should be separated from the spatulator (Fig. 14–25E).

The investment-filled casting ring is separated from the spatulator lid (Fig. 14–25F), vibrated lightly (Fig. 14–25G), and then set aside until the investment has hardened. Before the investment sets, the bowl, spatulator, and vacuum line must be cleansed impeccably of any investment that may have accumulated.

This technique is well suited for use with gypsum-bonded investments because of their fluidity after mixing. However, it is not generally used with phosphate-bonded investments because the greater viscosity of this material can trap air in sharp corners of the pattern.

Vacuum Mixing and Hand Investing Technique

Another technique involves only mixing the investment under a vacuum and then applying it by hand to the wax pattern with a brush (Fig. 14–26A, B, C). This procedure can be used with any investment but is most useful when a phosphate-bonded investment is being used because of its greater viscosity. After the pattern has been coated with investment, the metal ring is

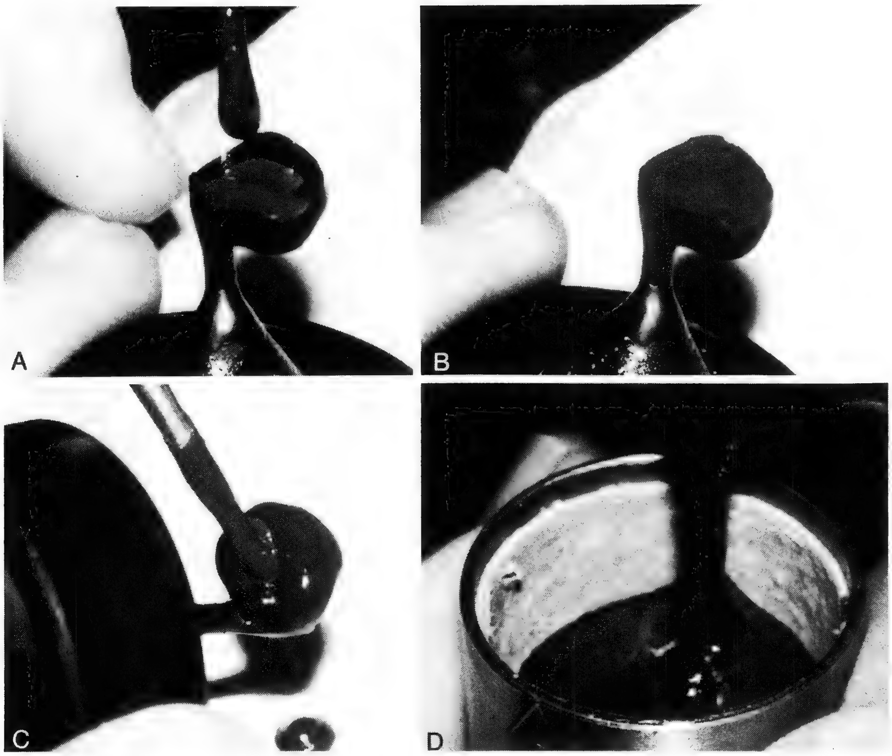


FIGURE 14–26

A, Vacuum-mixed investment applied to pattern by brush while crucible former is gently agitated on mechanical vibrator.
B, Pattern completely filled with investment.
C, Investment painted into occlusal grooves and fossae to prevent air entrapment when investment is poured into ring.
D, Investment being poured from mixing bowl down side of ring.

positioned on the crucible former, and investment is poured around the pattern until the ring is filled (Fig. 14–26D). Judgment must be used to determine the amount of investment that can be mixed in a bowl, since an overloaded bowl causes investment to be pulled into the vacuum line and mixer. The small-sized bowl may not prepare enough investment to fill two casting rings without inadvertently forcing investment into the vacuum hose or mixer.

Hygroscopic Technique

In the hygroscopic technique, after the wax pattern has been invested in an investment designed for hygroscopic expansion, the casting ring is immediately immersed in a water bath at a temperature of approximately 38° C (100° F).

In most of the present hygroscopic expansion techniques, the degree of hygroscopic expansion sought is controlled by regulating the water-powder ratio. Generally, the thicker the investment mix the greater is the hygroscopic expansion. Also, the longer the delay in time before the investment is immersed in the water bath, the less is the hygroscopic expansion. With some investments the expansion may be increased by using warmer water.

After the investment has hardened, the ring is removed from the water bath and the burnout is completed.

Controlled Water-Added Technique

In this technique, a soft flexible rubber ring is employed instead of the conventional lined metal ring. The pattern is invested normally. A specific amount of water is added on the top of the investment in the ring, and the investment is allowed to set, usually at room temperature. It is contended that the degree of hygroscopic expansion caused by the added water may be controlled by the amount of water used.

It should be reemphasized that several investing techniques can produce comparable results. The dentist or technician should become familiar with different methods to find the one that works best in his hands. In any technique, however, the fundamentals described here will be applicable.

15

CASTING AND FINISHING

NOBLE METAL CASTING ALLOYS

Noble metal casting alloys can be classified in a variety of ways. One is by function. The Bureau of Standards many years ago established classes, Types I through IV, according to the properties needed for the particular usage intended. Later the metal-ceramic alloys were introduced and added to such a classification. Thus, the following categories can be defined:

Type I (Soft). Small inlays that are easily burnished and subject to very slight stress.

Type II (Medium). Inlays subject to moderate stress.

Type III (Hard). Inlays subject to high stress; average thickness partial veneer and full veneer crowns; components of short-span (three-unit) fixed prostheses of average thickness. Type III alloys usually can be age-hardened.

Type IV (Extra Hard). Inlays subject to very high stress, removable partial denture components and frameworks, and long-span fixed prostheses. (Partial veneer crowns, pinledge retainers, and full crowns are often made of this type of alloy when maximal rigidity is desired.) These alloys can be age-hardened by an appropriate heat treatment.

Metal-ceramic (Hard and Extra Hard). Compatible for veneering with dental porcelain. Single restorations and short-span bridges are usually fabricated with the hard alloys and long-span bridges with the extra hard alloys. These restorations are discussed in Chapter 22.

Types by Alloy Description

There has been an esthetic preference for the yellow color as opposed to white metal for dental prostheses in which metal is exposed. However, with the wide acceptance of porcelain veneers, little metal is customarily visible in modern dental restorations, so the preference for yellow color is no longer as important. With the sharp rise in the price of gold, there has been a notable trend toward use of the less expensive white dental alloys.

The *white golds* are alloys that are predominantly gold in composition but that are whitened with appreciable amounts of palladium or with palladium and silver. *Low golds* are crown and bridge alloys with gold content lower than in the Type III and Type IV compositions. Yellow-colored alloys with as little as 42 per cent gold have been used successfully as dental alloys. White precious metal alloys are usually palladium-dominant alloys. Palladium-silver alloys are, as the name implies, palladium- and silver-based, with or without a small gold content. These are frequently referred to as "semi-precious" alloys, but this term is confusing. There is no accepted dividing line in terms of composition to distinguish between precious and semiprecious alloys. In general, the term "semiprecious alloy" should be avoided.

Composition and General Features

Table 15–1 lists eight alloys that are considered representative of modern dental alloys. This list does not, of course, exhaust the varieties that are available, but these are by far the most popular alloys. Different manufacturers have alloys that vary somewhat in gold, copper, silver, platinum, and palladium content. However, the major differences occur in the minor constituents, and these details are usually proprietary.

It should be mentioned that all modern noble dental alloys are generally fine-grained. This composition is accomplished by additions of very small quantities of iridium, ruthenium, or rhenium. Zinc is added primarily as an oxygen scavenger.

Copper is the principal hardener. In excessive amounts, copper tends to redden the yellow alloys and reduces resistance to tarnish and corrosion. Silver helps to minimize the reddening effect of copper.

Palladium has been substituted extensively for platinum in most of the yellow gold Types I to IV alloys. It serves to harden the alloy but also whitens it and raises the fusion temperature if appreciable amounts are added.

The Types III and IV *yellow gold* alloys in Table 15–

TABLE 15–1. TYPICAL COMPOSITIONS OF SOME MODERN NOBLE DENTAL ALLOYS

	Per Cent Gold	Per Cent Copper	Percent Silver	Per Cent Palladium	Indium, Tin, Iron, Zinc, Gallium
Type I (yellow gold)	83	6	10	0.5	Balance
Type II (yellow gold)	77	7	14	1	
Type III (yellow gold)	75	9	11	3.5	
Type III (low gold)	46	8	39	6	
Type III (silver-palladium)			70	25	
Type IV (yellow gold)	69	10	12.5	3.5 (+3.0 platinum)	
Type IV (low gold)	56	14	25	4	
Type IV (silver-palladium)	15	14	45	25	

1 are conventional American Dental Association high-gold alloys whose compositions probably date back to the 1940s. Although the use of these alloys is decreasing as a result of economic pressures, it is still significant. More importantly, these alloys have been developed and tested over a long time. Their handling characteristics and clinical performances are well established. Thus, they serve as a bench mark against which the characteristics and performance of the more recently developed alternative alloy systems can, and should, be compared. Hence their inclusion in Table 15–1 is warranted, although they are not actually new developments.

A major difference between the Type II silver-palladium white alloys and the Type IV silver-palladium white alloys is that the latter can be significantly age-hardened by heat treatment because of the gold and copper content. This alloy is one of the few examples in dental metallurgy in which gold is added not so much for its nobility and color but for its age-hardening effect.

Heat Treatment of Noble Metal Alloys

Gold alloys can be significantly hardened if the alloy contains a sufficient amount of copper. Types I and II alloys usually do not harden or harden to a lesser degree than do the Types III and IV alloys. Although the precise mechanism may be unknown, the criteria for successful hardening are not: they are time and temperature.

Alloys that can be hardened can, of course, also be softened. In metallurgic terminology, the *softening heat treatment* is referred to as solution heat treatment. The hardening heat treatment is termed *age-hardening*.

Optimal alloy hardening is advantageous for fixed prostheses and thinner castings such as partial-coverage restorations, since age-hardening substantially increases the *yield strength*. The yield strength reflects the capacity of an alloy (and hence the cast prosthesis) to withstand mechanical stresses without permanent deformation.

Hardening Heat Treatment

The age-hardening, or hardening heat treatment, of dental alloys can be accomplished in several ways.

One of the most effective hardening treatments is to "soak" or age the casting at a specific temperature for a definite time, usually 15 to 30 miniutes, before it is water-quenched. The aging temperature depends on the alloy composition but is generally between 200° C (400° F) and 450° C (840° F). The proper time and temperature are specified by the manufacturer.

A less effective but easier hardening treatment is to bench cool the casting ring for a specified period of time prior to quenching in water. A small casting ring is bench cooled for approximately 5 minutes and then quenched. Larger rings with greater bulk of investment require 15 to 30 minutes of cooling prior to quenching. Quenching in water immediately after casting leaves the restoration in a softened annealed state. This is not recommended for partial-coverage restorations or fixed prostheses unless the restoration subsequently will be aged to improve its hardness.

Recycling Noble Metal Casting Alloys

The completed casting always includes excess metal, such as that contained in the sprue button or chill sets. Owing to the intrinsic value of the precious metals contained in the alloy, the net materials cost of the casting can be substantially reduced if such scrap metal can be recycled. One obvious alternative is to collect such scrap and return it to the alloy supplier for credit.

However, the noble metal casting alloys are sufficiently stable that they can be recast two or three times without appreciable change in composition. The only elements likely to be lost are the more volatile base metals, such as zinc and indium, so long as the alloy is not abused by substantial overheating. Compositional losses can be remedied by the addition of at least equal amounts of new alloy to the scrap for recasting. Alloy scrap should be carefully cleaned, and foreign material such as investment should be removed before reuse.

Because of the large number of different alloy types and variations in composition among different alloy manufacturers, it should be obvious that alloy scrap be segregated by type and manufacturer if it is to be recast. Indiscriminate combining of any alloy scrap results in an alloy of unknown composition and properties and is definitely contraindicated.

BASE METAL ALLOYS

Intensive research in the characterization of such alloys for this purpose began in the 1970s. At that time, the rapidly escalating price of noble metals stimulated a search for the development of alternate alloy systems. The established record of the chromium-cobalt-nickel alloys for removable prostheses made them the first choice as likely alternatives to gold-based alloys.

Although the subject of fixed prosthodontics encompasses both all-metal and metal-ceramic alloy applications, the demands of the metal-ceramic system are more restrictive, and virtually all of the commerical interest to date has been focused in that direction. Therefore, the discussion of base metal systems is restricted to those designed for metal-ceramic application, although much of the discussion is also germane to the all-metal restoration. The application of base metals to the fabrication of metal-ceramic restorations is discussed in Chapter 22.

CASTING PROCEDURES

The fundamentals associated with the casting process are common to both gypsum- and phosphate-bonded investments. Thus, although the following discussion focuses on gypsum investments, most of it is also appropriate for phosphate-bonded investments. Additional information relating specifically to phosphate-bonded investments can be found in Chapter 22.

After the investment has hardened for at least 1 hour, the wax elimination and heating of the investment to the casting temperature can be started. The crucible former is removed carefully, and any loose investment particles are eliminated with an instrument or brush to prevent them from being carried into the mold with the molten alloy, thereby forming a defect in the casting (Fig. 15–1).

WAX ELIMINATION

The wax pattern is eliminated from the mold by heat. In the thermal expansion technique, the casting ring containing the invested pattern is heated slowly to the temperature at which adequate thermal expansion of the investment is obtained, usually 685° C (1250° F).

Some of the melted wax is absorbed by the investment, and the residual carbon from the ignition becomes trapped in the investment. If the thermal expansion technique is employed, the mold is heated sufficiently so that a great deal of the carbon is removed in the form of carbon monoxide or carbon dioxide.

It is best to start the burnout while the mold is still wet. The water in the pores of the investment reduces the absorption of the wax, and as the water boils, it tends to flush the wax out. This is facilitated by placing the ring in the furnace with the sprue hole down. For these reasons, if the mold must be stored overnight, it should be kept in a humidor or soaked in water for a few minutes prior to heating.

In the hygroscopic technique, the ring is heated to a temperature no higher than 480° C (900° F) because an appreciable thermal expansion of the investment is not desired.

Muffle furnaces are often so airtight that burnout takes place in a reducing atmosphere, preventing complete oxidation of the wax residues. Keeping the door open slightly permits air to enter and provides enough oxygen for elimination of the wax. This is particularly important for the hygroscopic expansion technique when a lower burnout temperature is used.

The rate at which the investment is heated is a factor in producing a smooth surface on the casting. If heating is too rapid at the start, the steam resulting from the elimination of the free water and water of crystallization may cause the walls of the mold to flake off as the steam emerges from the investment.

Too rapid heating may also cause cracking in the investment. In such a case, the outside layer of the investment becomes heated before the center portions. Consequently, the outside layer starts to expand thermally, so that compressive stress in the outside layer counteracts tensile stresses in the middle regions of the mold. Such a stress distribution causes the brittle investment to crack from the interior outwardly in the form of radial cracks. These cracks in turn produce a casting with fins or spines. Safe heating of the investment can be accomplished by allowing not less than 60 minutes for the furnace to reach the maximal burnout temperature.

In the thermal expansion technique, the ring is placed in a furnace at room temperature. In the low-heat hygroscopic technique, the ring can be placed in an oven preheated to 480° C (900° F) without fear of the investment cracking during the wax elimination.

The ring is placed into a burnout furnance (Fig. 15–

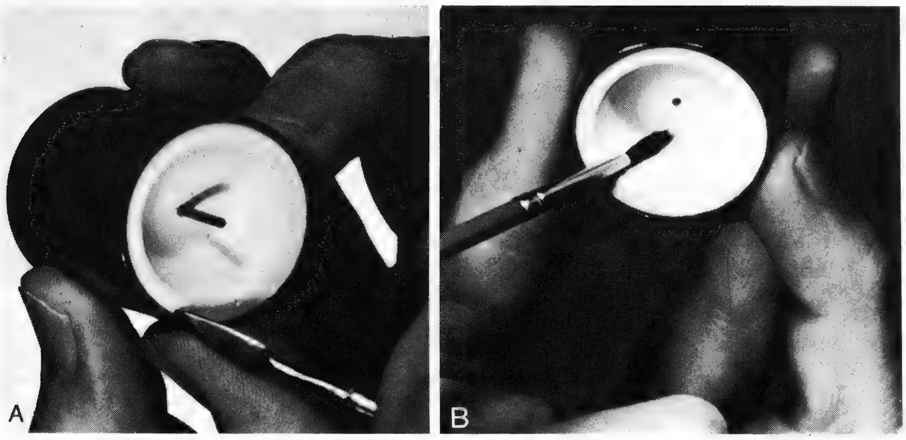


FIGURE 15–1

A, Loose investment particles being removed with a metal instrument.
B, Use of a soft brush for cleaning.

FIGURE 15–2 Neymatic 101AT burnout furnace. (Courtesy of The J. M. Ney Co.)

2) so that the crucible end is in contact with the bottom of the muffle. This position permits some of the wax to drain out of the sprue. It also prevents any small fragments of investment that may become dislodged during the wax elimination from falling down into the mold. If the ring is resting directly on the surface of the furnace muffle, the position of the ring should be reversed near the end of the burnout period. With the sprue hold facing upward, oxygen can more readily contact the wax and ensure complete elimination. Sometimes the ring is placed on perforated or slotted ceramic trays. In such a case, the circulation of air beneath the ring is adequate, and it is not necessary to invert the ring.

With the thermal expansion technique, the heating is continued until a temperature of 685° C (1250° F) is reached, as indicated by a pyrometer. At this temperature, the investment is cherry red when it is viewed in a shadow. In direct light, this color is an indication of a much higher temperature. If gypsum-bonded investment is heated to too high a temperature (over 700° C [1292° F]), a rough casting results, as well as possible contamination of the gold alloy with sulfur, because of the chemical disintegration of the investment.

Consequently, the furnace should be equipped with an accurate pyrometer and thermocouple. Furthermore, after the casting temperature has been obtained, the casting should be made immediately. Maintenance of the high casting temperature for any considerable time period may result in sulfur contamination of the casting and also in a rough surface on the casting, owing to the disintegration of the investment.

Because the wax is eliminated less rapidly in the low-heat technique, the ring should be held at the casting temperature of 480° C (900° F) for a minimum of 45 minutes in order to ensure complete wax elimination.

Time Allowable for Casting

The investment contracts thermally as it cools, as noted previously. When the thermal expansion technique is used, it can be expected that after the heated ring has been removed from the furnace, the investment loses heat, and the mold contracts. Owing to the presence of the ring liner, and to the low thermal conductivity of the investment, a short time can elapse before the temperature of the mold is appreciably affected. Under average casting conditions, approximately 1 minute can pass without a noticeable loss in dimension.

In the low-heat casting technique, the temperature gradient between the investment mold and the room is not so great as that employed with the high-heat technique. Also, the thermal expansion of the investment is not so important to the shrinkage compensation. However, the burnout temperature lies on a fairly steep portion of the thermal expansion curve rather than on a plateau portion as in the high-heat technique. Therefore, in the low-heat casting technique, the alloy should also be cast soon after removal of the ring from the oven.

CASTING

Equipment

The burnout oven and the casting machine must be conveniently located relative to one another to avoid any time loss during the actual casting process. There are three types of casting machines available. One makes use of air pressure (Fig. 15–3) to cast the molten

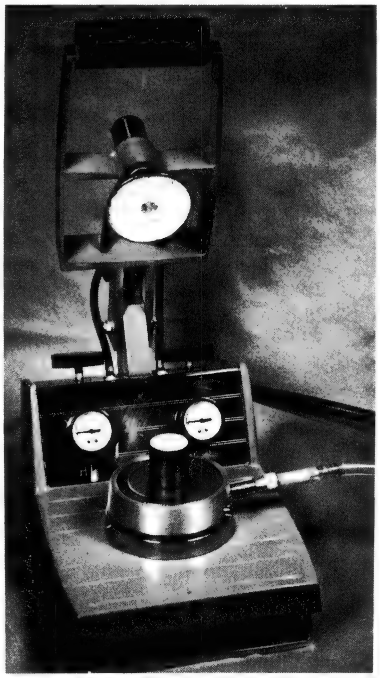


FIGURE 15–3 An air-pressure casting machine with the ring in position. The gold alloy is melted directly in the crucible formed in the investment. Above the ring can be seen the piston through which the air pressure is applied to force the molten alloy into the mold. The table below the ring may be connected to a source of vacuum, which is activated just before the pressure starts. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 434.)

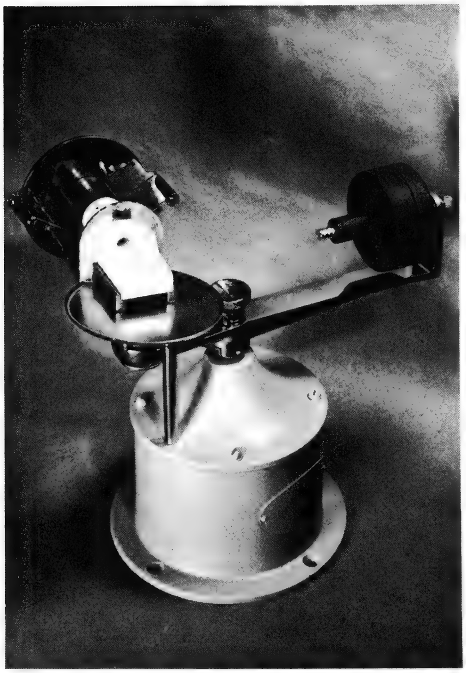


FIGURE 15–4 A centrifugal casting machine. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 434.)

alloy into the mold, whereas a second type (Fig. 15–4) is a spring-wound centrifugal casting machine. With both of these machines, the alloy is melted with a torch. The third type of casting machine (Fig. 15–5) is a spring-wound centrifugal casting machine with an attached electrical resistance melting furnace. The alloy is electrically melted in the furnace and then centrifugally cast into the mold, so that there is no need for a torch.

With the air-pressure machine, the alloy is melted in the investment crucible, and the molten gold is forced into the mold under air pressure. The alloy is premelted on a charcoal block before the ring is removed from the furnace. While the ring is being placed into the air-pressure machine, the melted gold solidifies to allow transfer to the crucible, in which it can be quickly remelted and the casting completed.

In the more popular broken-arm centrifugal machine, the alloy is melted in a crucible separate from the ring. The arm of this machine is spring-loaded, and after the metal has fused the spring is released. The initial action is for the broken arm to whip into line, throwing the gold into the mold by centrifugal force. The machine continues to spin, and this permits continuous force on the metal until it has solidified. To provide adequate force, three or four counterturns to load the spring are sufficient for dental castings. As a precaution, the casting ring should be checked in the casting cradle to be sure that the crucible platform fully secures the ring against the headplate of the casting machine. If the ring is not secure, it can roll out of position upon release of the arm, and the alloy will not hit the sprue opening. This can be prevented by placing a layer or two of asbestos or ceramic ring liner between the ring and the headplate.

When the electrical resistance melting furnace casting machine is used, the alloy is melted in a graphite crucible rather than by use of a flame. This is an advantage, especially for certain alloys, such as those used for metal-ceramic restorations, which are delicately alloyed with trace base metals that tend to oxidize on overheating. Another advantage is that the crucible in the furnace is located flush against the casting ring. Therefore, the button remains molten slightly longer, again ensuring that solidification progresses completely from the tip of the casting to the button surface. However, a carbon crucible should not be used in the melting of alloys with high palladium content or with base metal alloys.

So far as is known, there is no practical difference between the physical properties or in the accuracy of castings obtained with any of the machines as long as they are operated properly.

Casting Procedure

When a torch is used, the major objective in the melting procedure is to develop the most efficient gas-air flame that quickly yet cleanly melts the metal. The temperature of the flame is easily influenced by the relative proportions of gas and air. The gas is turned on and ignited and roughly adjusted to develop the size of flame that works best. Then the air is turned on to again roughly establish the melting flame, with final adjustments made using the air control, until a well-defined inner blue cone is attained.

The parts of the flame can be identified by the conical areas (Fig. 15–6). The innermost blank-appearing cone (Zone A) directly emanating from the nozzle is the zone in which the air and gas combine prior to combustion.

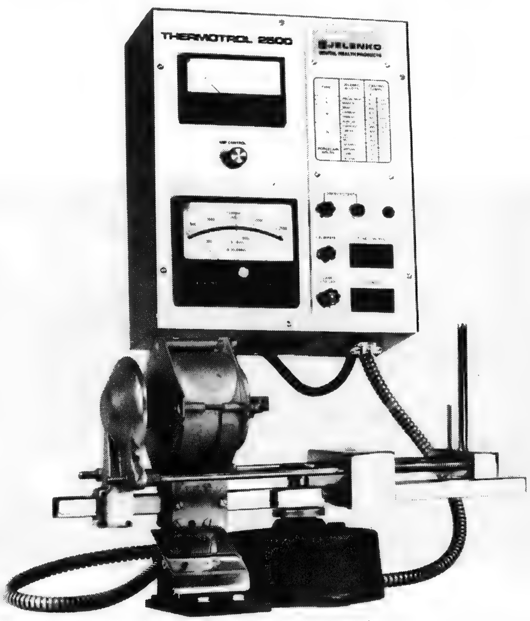


FIGURE 15–5 A spring-wound electrical resistance melting furnace casting machine. (Courtesy of J. Tuccillo, Jelenko Co.; from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 435.)

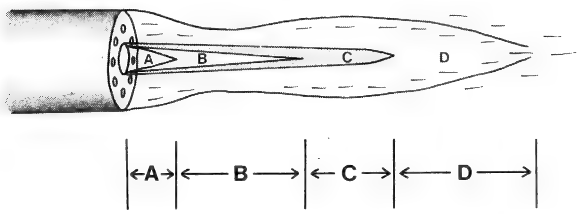


FIGURE 15–6 Conical Areas Present in a Properly Adjusted Flame

A, Zone in which gas and air are mixed prior to combustion.
B, Combustion zone.
C, Reducing zone.
D, Oxidizing zone. The tip of zone C should be used to melt the alloy.

The next cone (Zone B) is slightly greenish and immediately surrounds the first, or inner, cone. This is the combustion zone, in which the gas and air are in partial combustion. This zone is an oxidizing area and should be kept away from the metal during fusion. The next zone has a bluish cast and is the reducing zone; this is the hottest part of the flame (Zone C). The area near the tip of this cone is the part of the flame that must stay on the metal during fusion. Beyond this is the outer, or oxidizing, zone, in which combustion occurs with the oxygen of the air (Zone D). This part of the flame should never be used to melt the alloy, since its temperature is too low and it causes oxidation of the metal.

Beginners tend to allow an excessive air supply into the flame adjustment, producing a roaring sound that tends to make it "sound hot" when in fact it is a cool flame. Also, the tip of the reducing cone is not as well defined (Fig. 15–7).

Traditionally, asbestos has been used to line the casting crucible. It is moistened and adapted to the concave base of the crucible, then heated, and when dry provides a good surface on which the alloy can be melted. A liner facilitates melting of the alloy, since it insulates the metal from the crucible, which would otherwise draw heat from the alloy. It also prevents the melt from being contaminated with oxides and fluxes that may be present in the crucible. When an asbestos liner is used, it should be changed after every few castings.

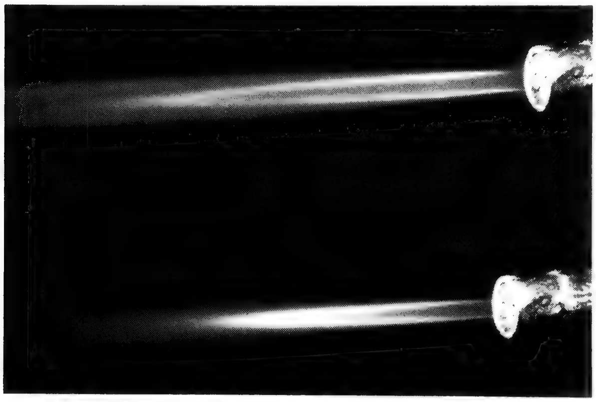


FIGURE 15–7 Two types of nonluminous flames showing combustion areas. The upper flame should be employed to fuse the noble metal alloy. The lower flame results from too much air in the mixture. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 436.)

Since asbestos is not readily available, and a suitable substitute for crucible lining has not been found, liners are not used as frequently as in the past. This presents no significant problems, except that the casting crucible should be discarded when it becomes obviously covered with oxides and contaminants from previous melts. Melting of the alloy is facilitated by torch heating of the casting crucible before the alloy is placed in the crucible.

When new metal is being used, it should be laid on the side of the crucible, for in this position it is possible to observe the progress of the melting. An ample amount of metal must be supplied, and as a general rule there should be as much metal in the sprue and button as is contained in the casting; frequently this amounts to 2 pennyweight (3 grams) or more of metal. The alloy first appears spongy, and then small globules of fused metal appear, following which the bulk of the alloy assumes a spheroidal shape and begins to slide down to the bottom of the crucible.

As the metal becomes fluid, it is always desirable to sprinkle a small amount of borax flux onto the metal. This helps to minimize porosity and to increase the fluidity of the metal, and the film of flux formed on the metal surface helps to prevent oxidation. Reducing

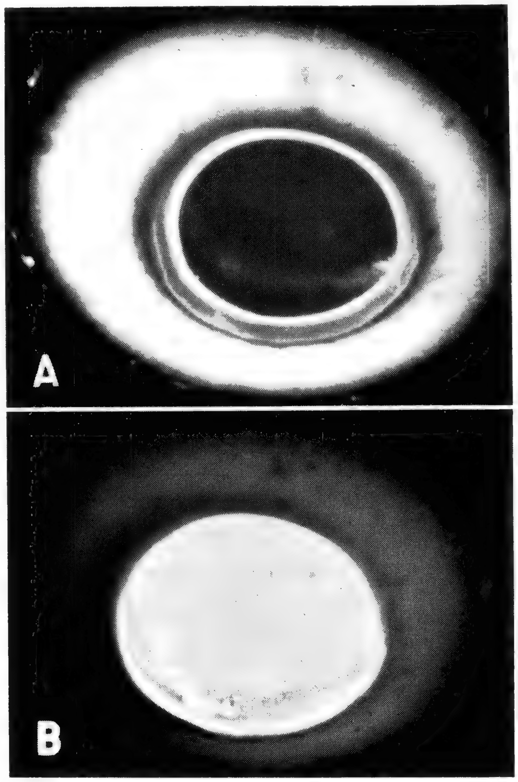


FIGURE 15–8

A, Mirrorlike surface of the metal indicates proper fusion.
B, Cloudy surface indicates surface oxidation by blowpipe flame. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 437.)

fluxes that contain some powdered charcoal are also used for this purpose. The flux should be applied before the ring is placed into the casting machine. Otherwise, particles of flux may be carried into the mold by the flame, which can cause pits in the casting.

If the casting is to be accomplished in a centrifugal machine, the ring is brought out of the burnout oven and placed securely in the casting cradle. If the ring has been notched for orientation of the pattern, placing the ring in the casting machine with the arrow straight up allows the margins and finer detail to be oriented toward the trailing edge, as discussed in Chapter 14.

The metal becomes very fluid and light orange in color and tends to spin as it responds to slight movement of the flame. Ideally at this point the temperature of the metal should be about 38° to 66° C (100 to 150° F) above its liquidus temperature. When this occurs, the casting is made immediately. If air-pressure casting is used, the flame stays on the metal in the crucible until the piston closes on the ring. If a centrifugal casting machine is used, the flame is not removed from the alloy until the casting arm is released. Overheating of the alloy, which must be avoided, is possible but is not likely to occur with a conventional gas and air torch.

With experience, it is possible to readily detect the proper zone in contact with the metal by observing the metal surface. When the reducing zone is in contact, the surface of the alloy is bright and mirror-like (Fig. 15–8A). Furthermore, the surrounding environment radiates the maximal intensity of color possible. This is in vivid contrast to the duller halo of the cloudy nonreflecting surface in the molten metal that occurs when the flame is applied improperly (Fig. 15–8B).

Cleaning the Casting

After the casting has been completed, the ring is allowed to bench cool for a specified time, as previously discussed, and then quenched in water. When the water contacts the hot investment, a violent boiling reaction ensues. Gypsum-bonded investments become soft and granular, and the casting is easily retrieved. Phosphate-bonded investments do not readily disintegrate on quenching, and the investment often must be cut with a plaster knife until the liner is exposed so that the investment can slide out of the casting ring. The investment is then split in half with a knife, and the excess material is mechanically removed from around and inside the casting with a sharp instrument (Fig. 15–9). Ultrasonic cleaning in detergent or the use of an air abrasive can be used to remove residual investment.

Quenching of the casting as soon as the button stops emitting a dull red glow leaves it in a softened annealed condition for burnishing, polishing, and similar procedures. The casting can then be hardened by aging at a given temperature. For a fixed prosthesis, the parts can be quenched, since subsequent slow cooling of the prosthesis after soldering produces some age-hardening of the metal.

Unless air abrasion is used, the surface of the casting appears dark with oxides and tarnish when investment removal is complete. Such a surface film can be removed by a process known as *pickling*, which consists of heating the discolored casting in an acid (Fig. 15–10). Probably the best pickling solution is a 50 per cent hydrochloric acid solution. The hydrochloric acid helps to remove any clinging investment as well as the oxide coating. The disadvantage of the use of hydrochloric acid is that the fumes from the acid are likely to corrode office and laboratory metal furnishings. A similar solution of sulfuric acid is more advantageous in this respect. Ultrasonic devices are also available for cleaning the casting, as are commercial pickling solutions of acid salts.

FIGURE 15–9 Castings after bulk of investment has been mechanically removed.

The best method for pickling is to place the casting in a test tube or dish containing the acid. Heating of the solution facilitates the oxide removal, but boiling should be avoided because of the considerable amount of acid fumes created. The pickling solution should be renewed frequently, since it is likely to become contaminated with use.

The casting must never be placed into the acid or removed with steel tongs so that both the casting and the tongs come into contact with the pickling solution. If this is done, the casting may be contaminated. The pickling solution usually contains small amounts of copper dissolved from previous castings. When the steel tongs contact this electrolyte, a small galvanic cell is created, and copper is deposited on the casting at the point at which the tongs grip it. This copper deposition extends into the metal and is a future source of discoloration in the area. Rubber-coated metal tongs or plastic tongs should be used.

Another technique is to heat the casting and then drop it into the pickling solution. The disadvantage of

FIGURE 15–10 Castings after pickling.

this method is that a delicate margin may be inadvertently melted in the flame, or the casting may be distorted by the sudden thermal shock when it is plunged into the acid.

After the pickling, the casting should be washed thoroughly in running water to ensure that the acid is completely removed.

CASTING DEFECTS AND THEIR CAUSES

An unsuccessful casting results in considerable aggravation and loss of time. In almost all cases, defective castings can be avoided by strict observance of the previously stated fundamental rules and principles. With present techniques, casting failures should be the rare exception, not the rule.

Defects in casting can be classified under four headings: (1) distortion, (2) surface roughness and irregularities, (3) porosity, and (4) incomplete or missing detail.

DISTORTION

Any marked distortion of the casting is probably related to distortion of the wax pattern. This type of distortion can be minimized or prevented by proper manipulation of the wax and handling of the pattern. Occasionally, improper orientation of the pattern in the investment or poor investment handling procedures can lead to an oversized mold that makes the casting appear as though the wax pattern was distorted.

SURFACE ROUGHNESS, IRREGULARITIES, AND DISCOLORATION

The surface of a dental casting should be an accurate reproduction of the surface of the wax pattern from which it is made. Excessive roughness or irregularities on the outer surface of the casting necessitate additional finishing and polishing, whereas irregularities on the internal surface prevent proper seating of an otherwise accurate casting.

Even under optimal conditions, the surface roughness of the dental casting is invariably somewhat greater than that of the wax pattern from which it is made. The difference is probably related to the particle size of the investment and its ability to reproduce the wax pattern in microscopic detail. Under proper manipulative techniques, the normal increased roughness in the casting should not be a major factor in dimensional accuracy. However, an improper technique can lead to a marked increase in surface roughness as well as to the formation of surface irregularities.

Air Bubbles

Nodules on a casting are caused by air bubbles that become attached to the pattern during, or subsequent to, the investing procedure. Such nodules can usually be removed if they are small and not in a critical area (Fig. 15–11). However, when they are present on margins or other critical areas, their removal might alter the fit of the casting. Large bubbles generally require fabrication of a new casting (Fig. 15–12). The best method to avoid air bubbles is to use the vacuum investing technique.

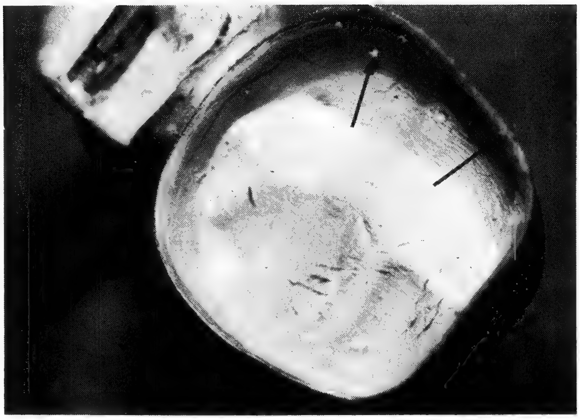


FIGURE 15–11 Small nodules resulting from air bubbles being trapped during investing. Two of the nodules have been marked by arrows.

A wetting agent may be helpful in preventing the collection of air bubbles on the surface of the pattern, but this is by no means a certain remedy. It is important that the wetting agent be applied in a thin layer. It is best to air-dry the wetting agent, since any excess dilutes the investment and causes a generally rough casting surface (Fig. 15–13).

Water Films

Wax is repellent to water, and if the investment becomes separated from the wax pattern in some manner, a water film may form irregularly over the surface. Occasionally, this type of surface irregularity appears as minute ridges or veins on the surface.

If the pattern is moved slightly, jarred, or vibrated after investing, or if the procedure does not result in intimate contact of the investment with the pattern, such a condition may result. A wetting agent aids in the prevention of such irregularity. Too high a water-powder ratio may also produce this effect.

FIGURE 15–12 Occlusal surface of mandibular molar casting covered by nodule.

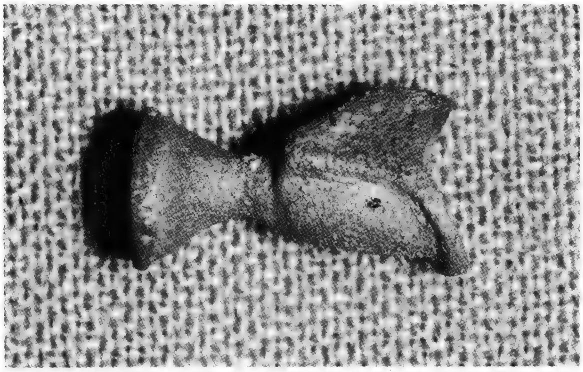


FIGURE 15–13 Wax pattern surface was covered with an excessive amount of wetting agent at the time of investing, resulting in a rough surface.

Too Rapid Heating

Overly rapid heating results in fins or spines on the casting (Fig. 15–14), or a characteristic surface roughness may be evident, owing to a flaking of the investment when the water or steam pours into the mold. The mold should be heated gradually. At least 60 minutes should elapse during the heating of the investment-filled ring from room temperature to 700° C (1292° F). The greater the bulk of the investment, the more slowly it should be heated.

Underheating

Incomplete elimination of the wax residues may occur if the heating time is too short or if there is insufficient air available in the furnace. These factors are particularly important with the low-temperature investment techniques. Voids or porosity may occur in the casting from the gases formed when the hot alloy comes in contact with the carbonaceous residues. Occasionally the casting may be covered with a tenacious-carbon coating that is virtually impossible to remove by pickling.

W/P Ratio

The higher the W/P ratio, the thinner is the investment and the rougher is the casting. Conversely, if too little water is used, the investment may be unmanageably thick, so that it cannot be properly applied to the pattern. In either case, a rough surface on the casting may result.

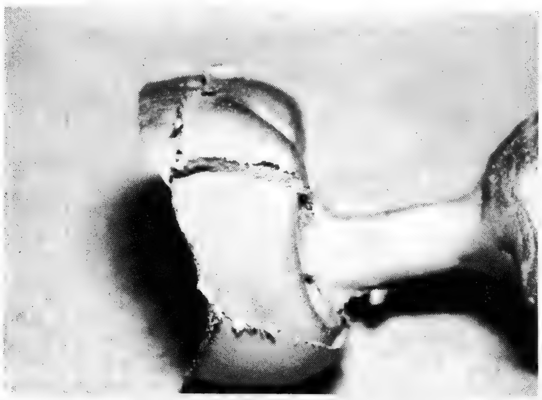


FIGURE 15–14 Casting fins caused by too rapid heating and cracking of investment.

Prolonged Heating

When the high-heat burn out technique is used, prolonged or excessively high heating of gypsum-bonded investments is likely to cause a disintegration of the investment, and the walls of the mold are roughened as a result (Fig. 15–15). Furthermore, the products of decomposition are sulfur compounds that may contaminate a noble metal to the extent that the surface texture is affected. Such contamination may be the reason the surface of the casting sometimes does not respond to pickling. When the thermal expansion technique is employed, the mold should be heated to the casting temperature, never higher than 700° C (1292° F), and the casting should be made immediately.

Temperature of the Gold Alloy

If the noble metal alloy is heated to too high a temperature before casting, the surface of the investment is likely to be attacked, and a surface roughness of the type described in the previous section may result.

Casting Pressure

Too high a pressure during casting produces a rough surface on the casting. A gauge pressure of 15 to 20 pounds per square inch (psi) in an air-pressure casting machine or three to four turns of the spring in an average type of centrifugal casting machine is sufficient for small castings.

Foreign Bodies

When foreign substances get into the mold, a surface roughness may be produced. For example, a rough crucible former, with investment clinging to it, may roughen the investment at removal, so that bits of investment are carried into the mold with the molten alloy.

FIGURE 15–15 Rough contaminated casting produced from investment breakdown caused by overheating.

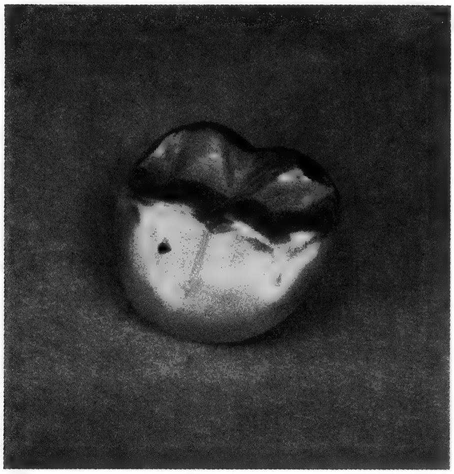


FIGURE 15–16 As the casting was polished, an investment particle was uncovered, revealing perforation.

Usually, contamination results not only in surface roughness but also in incomplete areas or surface voids. Any casting that shows sharp well-defined deficiencies indicates the presence of some foreign particles in the mold, such as pieces of investment (Fig. 15–16). Bright-looking concavities may be the result of flux being carried into the mold with the metal.

Impact of Molten Alloy

The direction of the sprue former should be such that the molten gold alloy does not strike a weak portion of the mold surface. Occasionally, the molten gold may fracture or abrade the mold surface as it strikes it, regardless of the surface configuration. Unfortunately, the abraded area is sometimes smooth so that it cannot be detected on the surface of the casting. Such a depression in the mold is reflected as a raised area on the castings and is often too slight to be noticed yet sufficiently large to prevent the seating of the casting. This type of surface roughness or irregularity can be avoided by proper attachment of the sprue former to prevent the direct impact of the molten metal at an angle of 90 degrees with the investment surface.

Other Causes

There are certain surface discolorations and roughness, which may not be evident when the casting is completed, but which may appear during service. For example, various gold alloys, such as solders, bits of wire, or various types of casting alloys, should never be melted together and reused. The resulting mixture would not possess the proper physical properties and might form eutectic or similar alloys with low corrosion resistance. Later discoloration and corrosion generally result during service.

Contamination with copper during improper pickling may be a factor in future surface change.

Porosity

Porosity may occur both internally and externally. The latter is a factor in surface roughness, but also it is generally a manifestation of internal porosity. Not only does the internal porosity weaken the casting; if it appears on the surface, it also may be a cause for discoloration. If severe, it can produce leakage at the tooth-restoration interface, and secondary caries may result.

FIGURE 15–17 Shrinkage porosity.

Porosities in noble metal alloy castings may be classified as follows:

1. Those caused by solidification shrinkage
   a. Localized shrinkage porosity
   b. Microporosity
2. Those caused by gas
   a. Pinhole porosity
   b. Gas inclusions
   c. Subsurface porosity
3. Those caused by entrapped air in the mold

Porosity caused by *localized shrinkage* (Fig. 15–17) is generally caused by incomplete feeding of molten metal during solidification. Therefore, there must be continual feeding of molten metal through the sprue to make up for the shrinkage of metal volume during solidification.

Localized shrinkage generally occurs near the sprue-casting junction. However, this type of void may also occur in the interior of a crown near the area of the sprue, if a hot spot has been created by the hot metal impinging from the sprue channel on a point of the mold wall. This hot spot causes the local region to freeze last and result in what is called *suck-back* porosity (Fig. 15–18).

FIGURE 15–18 Molar casting with perforation at point of sprue attachment.

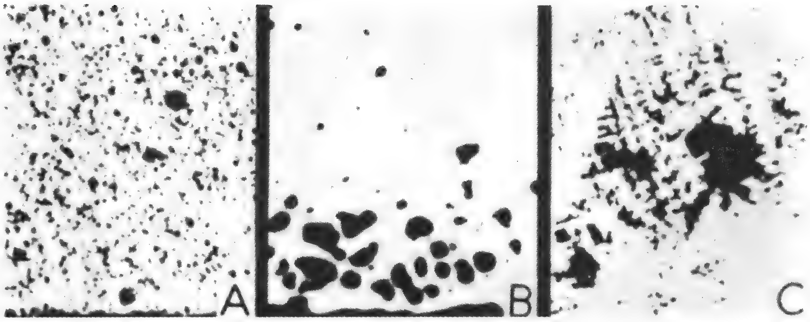


FIGURE 15–19
A, Microporosity, pinhole porosity, and gas inclusions. (Microporosity voids are irregular in shape, whereas the other types tend to be spherical; the largest spherical voids are gas inclusions.)
B, Subsurface porosity.
C, Localized shrinkage porosity.
(Courtesy of G. Ryge; from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 446.)

Such voids can be eliminated by (1) flaring the point of sprue attachment, as noted, and (2) reducing the mold-melt temperature differential, that is, by lowering the casting temperature by about 30° C.

Microporosity also occurs from solidification shrinkage but is generally present in fine-grain alloy castings when the solidification is too rapid for the microvoids to segregate to the liquid pool. Such phenomena can occur from unduly rapid solidification when the mold or casting temperature is too low. Unfortunately, this type of defect is not detectable unless the casting is sectioned. In any case, it is generally not a serious defect.

The *pinhole* and *gas inclusion* porosities are both related to the entrapment of gas during solidification. They are both characterized by a spherical contour but they are decidedly different in size. The gas inclusion porosities are usually much larger than the other type (Fig. 15–19).

Many metals while molten dissolve or occlude gases. Upon solidification, the absorbed gases are expelled, and the pinhole porosity results. Larger voids may also result from the same cause, but it seems more logical to assume that such voids may be caused by gas mechanically trapped by the molten metal in the mold or else carried in during the casting procedure.

All castings probably contain a certain amount of porosity. However, the porosity should be kept to a minimum because it may affect the physical properties of the casting deleteriously.

Oxygen is dissolved by some of the metals, such as silver, in the alloy while they are in the molten state. During solidification, the gas is expelled to form blebs and pores in the metal. This type of porosity may be attributed to abuse of the metal. Castings severely contaminated with gases are usually black when they are removed from the investment and do not clean easily on pickling. The porosity that extends to the surface is usually in the form of small pinpoint holes. When these holes are removed by polishing, others appear.

Larger spherical porosities can be caused by gas occluded from a poorly adjusted blowpipe flame or if the reducing zone of the flame is not used.

These types of porosity can be minimized by premelting the gold alloy on a charcoal block if the alloy has been used before and by correctly adjusting and positioning the blowpipe flame during melting.

Subsurface porosity occurs on occasion. As has been explained, this type of porosity can be diminished by controlling the rate at which the molten metal enters the mold.

Entrapped air on the inner surface of the casting, sometimes referred to as back-pressure porosity, can produce discrepancies such as those seen in Figure 15–20. This is the result of the inability of the air in the mold to escape through the pores in the investment or of the pressure gradient pushing the air pocket out via the molten sprue and button.

The entrapment is frequently found in a pocket at the cavity surface of a crown or a three-surface inlay (Fig. 15–20). Occasionally it is even found on the outside surface of the casting when the casting temperature or mold temperature is so low that solidification occurs before the entrapped air can escape.

Proper burnout, an adequate mold and casting temperature, and a sufficiently high W/P ratio all help to eliminate this phenomenon. It is good practice to make sure that the thickness of investment between the tip of the pattern and the end of the ring not be greater than approximately 6.0 mm (1/4 inch). The use of vent rods does not seem to help this condition.

Incomplete Casting

Occasionally, only a partially complete casting, or perhaps no casting at all, is found. The obvious cause is that the molten alloy has been prevented, in some manner, from completely filling the mold. There are several factors that might inhibit the ingress of the liquefied metal. They are insufficient venting of the mold, incomplete elimination of the wax in the mold, high viscosity of the fused metal, and failure of the molten metal to enter the mold.

The first consideration, insufficient venting, is directly

FIGURE 15–20 Surface irregularity on cavity side of casting owing to back-pressure porosity. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 449.)

FIGURE 15–21 Rounded incomplete margins are evidence of insufficient casting pressure. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 451.)

related to the back pressure exerted by the air in the mold. If the air cannot be vented with sufficient rapidity, the molten alloy does not fill the mold before it solidifies.

In such a case, the magnitude of the casting pressure should be suspected. If insufficient casting pressure is employed, the back pressure cannot be overcome. Furthermore, the pressure should be applied for at least 4 seconds. The mold is filled and the metal is solidified in approximately 1 second or less, yet the metal is very soft during the early stages. Therefore, the pressure should be maintained for a few seconds beyond this point. An example of an incomplete casting caused by insufficient casting pressure is seen in Figure 15–21. These failures are usually exemplified in rounded incomplete margins.

A second common cause for an incomplete casting is incomplete elimination of the pattern. If too many products of combustion remain in the mold, the pores in the investment may become filled so that the air cannot be vented. If moisture or actual particles of wax remain, when the molten alloy contacts either of these foreign substances an explosion may occur. This may produce sufficient back pressure to prevent the mold from being filled. An example of a casting failure caused by incomplete wax elimination can be seen in Figure 15–22. Here the rounded margins are quite shiny rather than dull. This shiny condition of the metal is caused by the strong

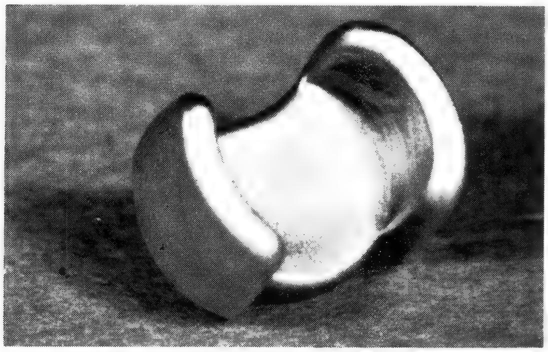


FIGURE 15–22 Incomplete casting resulting from incomplete wax elimination is characterized by rounded margins and shiny appearance. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 451.)

FIGURE 15–23 Incomplete molar casting resulting from insufficient heating of the alloy.

reducing atmosphere created by the carbon monoxide left by the residual wax.

High viscosity of the fused metal can be attributed to insufficient heating. The temperature of the alloy should be raised higher than its liquidus temperature so that its viscosity and surface tension are lowered and so that it does not solidify prematurely as it enters the mold (Fig. 15–23).

Occasionally, an incomplete casting is caused by the failure of a portion of the alloy to enter the mold. This can be caused by the ring rolling entirely or partially out of its cradle as the centrifugal casting machine is released, which can occur if the crucible platform does not stabilize the position of the ring against the headplate of the casting machine (Fig. 15–24).

FINISHING AND POLISHING

Trial Seating on Die

After careful evaluation of the casting to determine it to be acceptable, the internal surface should be inspected for positive irregularities that prevent complete seating on the die. A binocular dissecting microscope is very useful for looking at the surface and identifying nodules and irregularities. These can be removed with a small round bur (number 1/2 or 1) while the casting is examined under magnification (Fig. 15–25).

There are other methods for identifying internal areas of the casting that require adjustment. Colored liquids that rub off and transfer a mark when the casting is seated on the die can be used to detect positive irregularities. Pressure-blasting of the internal surface with 50-μ aluminum oxide produces a mat finish that is marked by the die in areas that require minor adjustment.

All of these techniques are designed for removing slight irregularities from an acceptable casting. Any casting that requires extensive adjustment of the internal surface because of gross nodules and irregularities should be discarded, and a new casting should be fabricated.

Marginal Fit on the Die

The marginal portion of the casting should be a continuation of the cervical contour of the tooth (Fig.

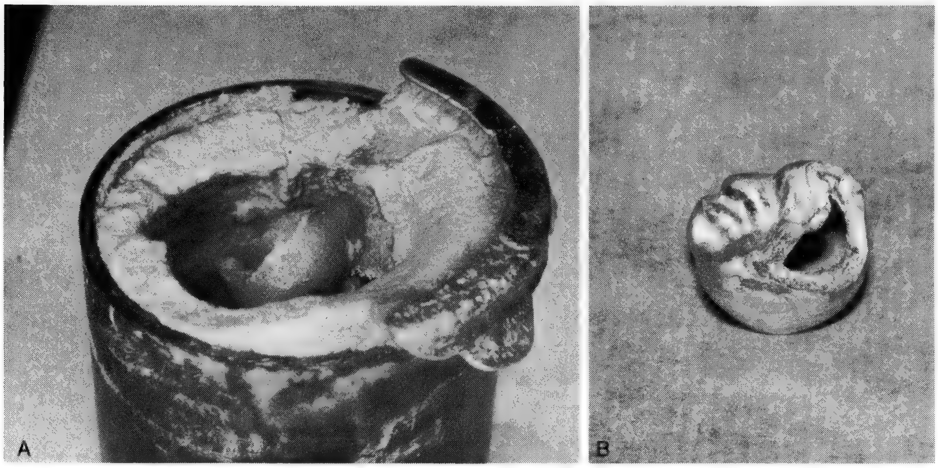


FIGURE 15–24
A, Investment and casting ring after quenching. The ring rolled partially out of its cradle as the centrifugal casting machine was released and a large portion of the alloy hit the perimeter of the investment and the end of the casting ring, freezing in that location. Only a small portion entered the mold.
B, Incomplete casting retrieved from mold.

15–26). This means that the metal must not be short of the margin of the preparation and that the casting must not extend beyond the prepared margin.

A casting that is short of the margin must be remade, since alloys used in a fixed partial denture have properties such that it is impossible to correct such a deficiency by burnishing. Discrete marginal burnishing is an acceptable step in the polishing of a properly fitting casting but will not adequately close a margin short of the finish line. In some cases, when the casting margins are sufficiently long but project slightly lateral to the finish line, burnishing of the margins can correct the deficiency.

Internal Adaptation and Stability

The casting should fully seat on the die without binding and possess a level of internal adaptation that allows it to remain stable against tipping and twisting forces. Castings that depend primarily on the use of a luting agent to provide stability have questionable clinical value.

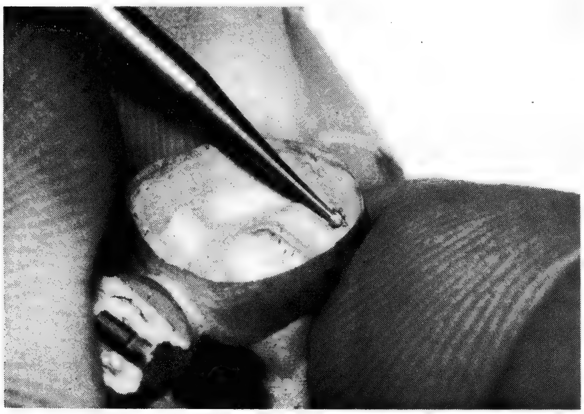


FIGURE 15–25 Removing nodules with number ½ round bur.

Sprue Removal

The sprue can be separated from the casting by the use of a carborundum disc in a slow-speed straight handpiece. In order to conserve metal, the cut should pass through the sprue as close to the casting as possible without altering the normal contour of the restoration. The use of a carborundum disc requires a firm grip on the handpiece and casting to prevent the disc from binding and caroming to another area of the casting, in which it can produce damage. Intermittent forceful contact of the rotating disc with the sprue helps to prevent this binding.

The sprue can be severed from the casting by the use of side cutting pliers, if the cut is kept away from the normal form of the casting. However, care must be taken, since thin castings or partial-coverage castings can be distorted by this technique.

After the sprue has been severed, the excess metal on that area of the casting is removed with a carborundum disc or other abrasive stone until normal contour is reestablished (Fig. 15–27).

Finishing and Polishing

Polishing of a casting is necessary to provide a surface that feels comfortable, does not readily accumulate debris and plaque, and is resistant to tarnish and corrosion. The objective of polishing is to remove surface imperfections by using a series of progressively finer abrasives until the surface is so smooth that it uniformly reflects light because of its high surface luster.

Single restorations are completely finished in the manner to be described, whereas retainers and pontics

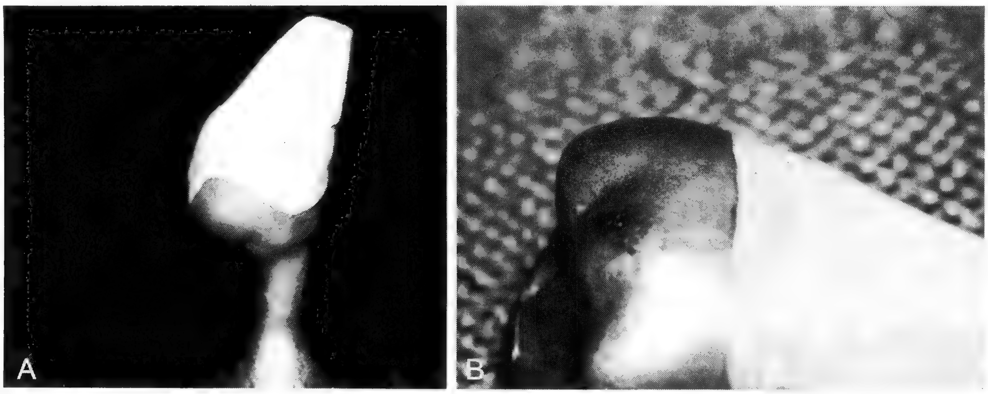


FIGURE 15–26

A, Premolar casting seated on stone die.
B, Molar casting seated on stone die showing marginal fit and contour.

only undergo preliminary adjustments, with the final polishing of the prosthesis being completed after assembly by the soldering process (see Chapter 16). The abrasives commonly used for polishing of castings include garnet, sandpaper, and cuttle discs, rubber wheels impregnated with abrasive material, and finer agents such as tripoli and rouge. With a smooth wax pattern and proper handling of the investing and casting, the restoration does not require extensive polishing, and coarser abrasives such as the garnet disc are needed only where the sprue was removed. Medium and fine cuttle discs are adequate for most polishing.

Castings should be adjusted and polished on the working cast and die prior to clinical trial insertion. Although clinical adjustments are made that roughen certain polished areas, it is more time-efficient to have all surfaces well polished and to repolish only the adjusted areas rather than to perform all final polishing after clinical adjustments are complete.

Proximal Contact Adjustment

The proximal contact areas require a slight adjustment to allow the casting to completely seat on the working cast. This is done by careful polishing with a cuttle disc or a fine-grit rubber wheel to avoid losing contact with adjacent teeth (Fig. 15–28). The adjacent stone teeth can be coated with a colored liquid or marked with pencil lead that transfers a mark when the casting is seated to indicate where adjustment should be made. Articulating paper or tape can also be placed between the casting and adjacent teeth to produce a colored mark on the casting.

The loss of proximal contact from overpolishing must be corrected by adding solder to the deficient area, since slightly open contacts lead to interproximal food impaction and difficulty in maintaining gingival health.

The safest way of adding solder proximally is to embed the casting margin in soldering investment or asbestos so that it is protected and then to heat the casting and make the solder flow with a torch. Another method of adding solder to a proximal contact area is to heat the casting by holding it with soldering tweezers in a Bunsen burner flame.

Gold solder with a fineness of 650 is recommended because of its greater resistance to tarnish and corrosion as compared with less fine solders. This solder flows at 821°C (1510° F), which is about 66° C (150° F) below the

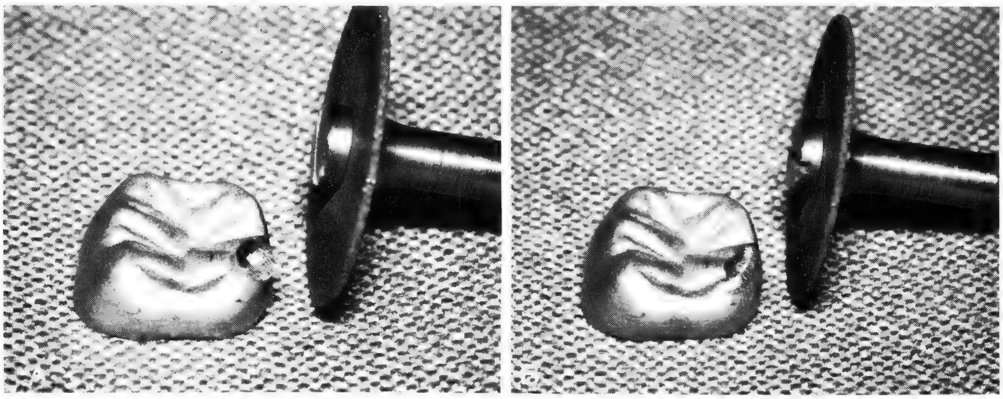


FIGURE 15–27

A, Sprue severed with separating disc to leave slight excess.
B, Normal contour reestablished.

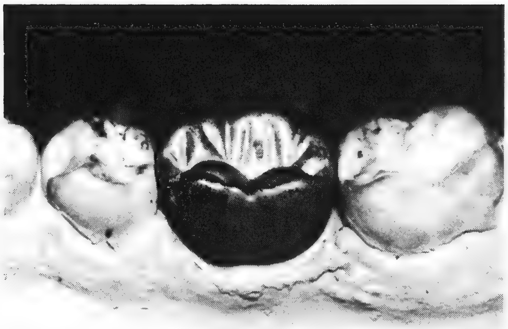


FIGURE 15–28 Proximal surfaces of casting adjusted to allow complete seating.

FIGURE 15–29 Articulating paper produced marks on casting and not on surrounding teeth, which indicates that occlusal adjustment is necessary.

melting range of the gold alloys commonly used in fixed prosthodontics. Therefore, there is little danger of melting or distorting the casting if the soldering technique is properly followed.

An antiflux can be used to limit the extent of solder flow. When applied to an area, this prevents solder from attaching itself to the underlying metal. Gold rouge is an excellent material that can be mixed with chloroform and painted on areas in which solder should not flow. Marking of the perimeter of the deficient area with soft pencil lead also prevents solder from flowing beyond the desired area.

A small amount of soldering flux is applied to the deficient area, and a piece of solder is coated with flux and set aside. The amount of solder used should correct the deficiency and provide a slight excess for finishing. The casting is heated with a torch until it manifests a reddish glow when the torch is removed. The piece of solder is then picked up with soldering tweezers and quickly placed in contact with the inadequate proximal area so the heating process can be continued until the solder flows. Solder flows toward the hottest area, and the direction from which the flame is applied can be used to help direct the flow. If the solder is placed on a crown at room temperature and then heat is applied, more porosity is produced than if the solder is applied after heating the casting to the point at which it begins to exhibit a reddish glow.

If the casting is being held in the Bunsen burner flame with soldering tweezers, care must be exercised to keep the margins out of direct contact with the flame.

Following soldering, the casting is again pickled and the excess solder is removed by careful polishing. It is important to achieve a smooth transition between the solder and the parent metal.

Occlusal Surface Finishing

Although the last occlusal adjustments are accomplished clinically, it is easier and more time-efficient to complete the majority of these corrections on the working cast.

This is accomplished by using two colors of articulating paper or tape (one lighter color and one darker color, such as a red and a blue). The light color is used to evaluate eccentric occlusal relationships and the dark color for centric occlusal adjustments.

The darker material is placed between the restoration and the opposing teeth of the articulated casts, and the teeth are tapped together in centric occlusion. Marks appear on the casting wherever it contacts opposing teeth, and these marks are evaluated for uniformity of contact with the remainder of the dentition (Fig. 15–29). Generally, the unfinished casting comes in contact before any other teeth. However, if the restoration is out of occlusal contact, it is necessary to fabricate a new casting. With a casting that contacts prematurely, minor adjustment of the occlusal surface is necessary to bring the other teeth into contact. This is done by grinding the largest and darkest marks with a medium-grit stone in a slow-speed handpiece. Contact marks that have the form of a halo, with no central color, are indicative of the more premature areas of contact. As the unrestored teeth just begin to make contact, it is advisable to switch to a rubber instrument that is not as abrasive and to begin to polish the roughened areas while refining the occlusal contact relationship.

At this point, eccentric movements are generated with the light-colored marking material placed between the casts. The casts are then brought into contact only in centric occlusion using the darker-colored material. The dark centric occlusal contacts can now be readily differentiated from any eccentric occlusal contacts indicated by the lighter-colored markings. As was discussed in conjunction with the wax pattern formation, eccentric occlusal contact of posterior teeth should be eliminated. Posterior castings are adjusted so the light-colored marks are eliminated while the darker centric occlusal contacts are retained.

The occlusal grooves are refined, and any nodules or

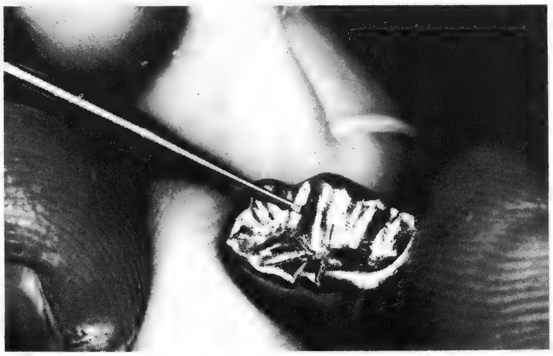


FIGURE 15–30 Occlusal grooves refined and nodules removed as necessary with small inverted cone bur.

irregularities are removed using a small inverted cone bur in a slow-speed handpiece (Fig. 15–30). The casting is now ready for the final polishing of the axial and occlusal surfaces.

Final Polishing

The axial surfaces are first polished to within 1 mm of the margin by using a series of different grits of abrasive discs* (Fig. 15–31A, B). The fine garnet disc is used only on rough areas such as where the sprue was severed or where occlusal grinding was performed. The medium cuttle disc is then used over all but the marginal areas of the casting, followed by the fine cuttle disc, until a smooth satiny finish is achieved. Alternately, rubber instruments can be used in the same manner. Polishing in several different directions ensures that a smooth surface is achieved, whereas polishing in only one direction often leads to the development of surface undulations. It is important to produce a uniformly smooth surface before proceeding with further polishing. Care must be exercised not to cause the loss of proximal contacts by overpolishing these areas.

The remaining unpolished marginal area is burnished with an instrument possessing a slightly blunted blade (Fig. 15–31C). This is done to smooth the area without abrasive removal of metal. The marginal, occlusal, and axial surfaces are then polished with a fine cuttle disc or a fine rubber instrument. Approaching the margin from the occlusal area and polishing this area without allowing the disc to cross the metal margin avoids

*E. C. Moore Company, Dearborn, MI 48126.

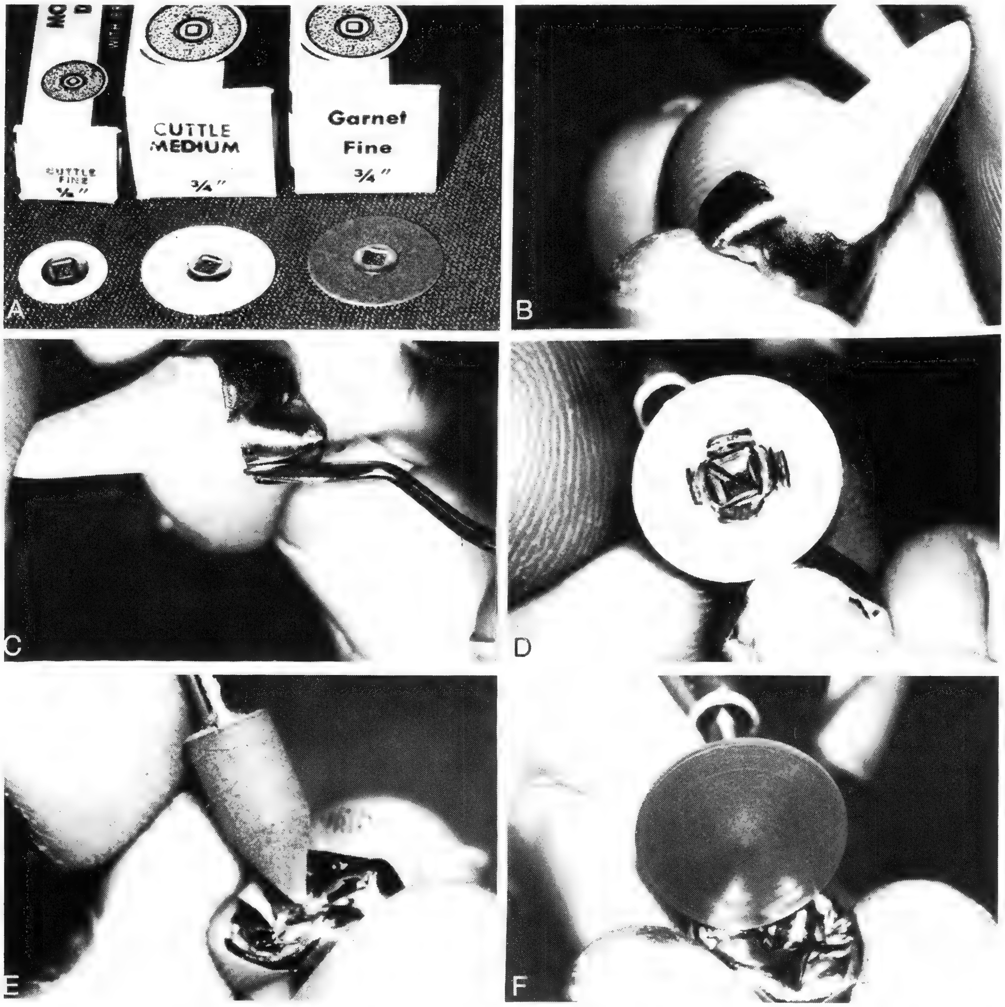


FIGURE 15–31

A, Three grits of abrasive discs used in polishing.
B, Casting polished to within 1 mm of margin until a satin finish is achieved.
C, Metal instrument used to burnish unpolished marginal metal.
D, Fine cuttle disc contacting axial surface and then moved just to the margin from an occlusal direction.
E, Rubber point used to polish occlusal grooves.
F, Rubber wheel used on accessible grooves and ridges.

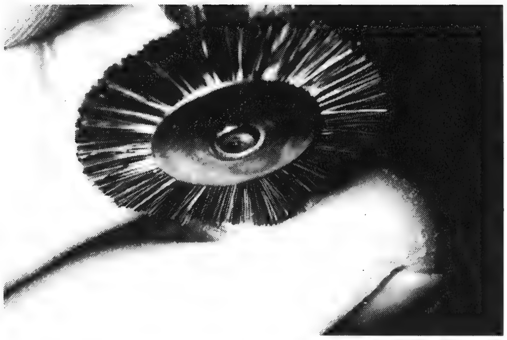


FIGURE 15–32 Tripoli being used with bristle brush on axial surface. Note that the margin is pressed into fingers to prevent rounding during polishing.

rounding of this critical area of the casting (Fig. 15–31D). Rubber points* and wheels† (Fig. 15–31E, F) are useful for polishing occlusal grooves and fossae.

Tripoli is then used on a wheel brush to produce the final smoothing of the axial surfaces and the ridges and grooves on the occlusal surface (Fig. 15–32).

*Brownie SHP wheels, Shofu Dental Corporation, Menlo Park, CA 94025.

†Brownie SHP points, Shofu Dental Corporation, Menlo Park, CA 94025.

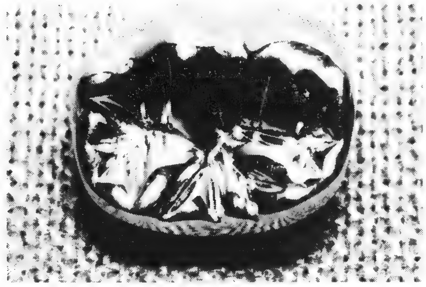


FIGURE 15–33 Finished casting after ultrasonic cleaning in a detergent solution.

The final luster is achieved with rouge on a leather chamois wheel. This polish is used on the axial surface but not on the occlusal surface, since the extreme light reflection from a highly lustrous surface can interfere with the intraoral evaluation and refinement of occlusal contact. Rouge can be used on the occlusal surface after clinical adjustments are complete.

Next the casting is cleaned ultrasonically for a few minutes in a detergent solution designed for removing polishing compounds, rinsed thoroughly with clean water, and dried (Fig. 15–33). The polishing procedures are evaluated, and any needed repolishing is accomplished. The casting is then ready for clinical trial insertion.

16

Fixed Partial Denture Assembly

When the components of a fixed partial denture are cast individually, they are joined by the soldering process. This involves recording the positional relationship of the retainers and pontic castings and aligning and holding the parts in the soldering investment. Solder can then be made to flow between the parts. This series of procedures requires extreme care if the assembled prosthesis is to accurately fit the prepared teeth.

PRELIMINARY CASTING ADJUSTMENTS

Certain adjustments must be made to the castings before their positional relationship to each other can be obtained. The proximal contacts of the abutment retainers with adjacent teeth are refined to allow complete seating on the working cast. Preliminary occlusal adjustments are completed and the axial surfaces finished until a satin surface is achieved. It is neither necessary nor advantageous to polish the margins prior to soldering, since soldering produces oxides that roughen the surface and necessitate repolishing (Fig. 16–1).

The proximal surfaces between the retainers and pontic are next adjusted to allow complete seating of the pontic between the retainers. When the pontic is cast separately and not attached to a retainer, the facial index obtained when the pontic was waxed can be used to orient the pontic. The ridge contacting surface of the pontic is then adjusted as necessary to permit complete seating on the working cast. Only the preliminary occlusal adjustment of the pontic is accomplished at this time, since the final adjustments are easier to perform after soldering, when the parts are rigidly connected.

FIGURE 16–1 Facial view after proximal contact adjustment to allow for complete seating. Note that the margins have not been polished and that a small gap is present between the pontic and the premolar retainer.

The amount of proximal adjustment is important, since the space between the pontic and abutment retainers affects the strength of the solder joints and the fit of the assembled prosthesis. If the parts are in contact, the solder joint strength may be reduced, and there may be a greater chance that the assembled prosthesis will not fit. A small gap of about 0.13 mm (0.005 inch) is considered advantageous in order to prevent warpage, whereas excessive gaps can increase distortion (Fig. 16–1).

The form of the proximal surfaces should facilitate the development of proper connector form, location, and size. The proximal surfaces should possess normal tooth contours. This places the point of greatest convexity far enough from the interdental soft tissue that a solder joint can be formed with the size needed for strength yet generally allowing access for proper cleansing of the soft tissue (Fig. 16–1). Under normal conditions, a posterior solder joint between a retainer and pontic having a buccolingual dimension of about 3 mm and an occlusocervical dimension of 2 mm adequately resists occlusal forces. Anterior solder joints in general are larger incisocervically than labiolingually and can be slightly smaller and still possess adequate strength. Connectors between adjacent retainers for multiple abutment prostheses or splinted restorations can also be smaller because of lower strength requirements.

THE SOLDERING INDEX

RECORDING METHODS

Different methods can be used to record the required relationships of the parts to each other and to the abutment teeth and ridge tissues. One method is to

clinically seat the retainers over the prepared teeth, position the pontic, and then obtain a record or index of the relationship. However, the difficulty of maintaining the pontic in position often makes this a complicated procedure. Another assembly process involves connecting part of the prosthesis from relationships that are present on the cast and the remainder from the mouth. A third method is to use only the working cast to obtain the index for assembly.

Accurate assembly can be achieved by any of these methods. However, use of the cast without taking the parts back to the mouth is successful only if there has been no movement of abutment teeth after the impression was obtained. Assembly from a working cast when the relationship in the mouth has changed invariably results in a prosthesis that does not fit.

Various factors can cause prepared abutment teeth to move after the impression has been obtained. Minor changes in the occlusal interdigitation of the temporary restoration that allows contact on different slopes of the occlusal surface can produce tooth movement. A slight change in the character of proximal contacts can cause or allow tooth movement. Occlusal wear of the temporary prosthesis or its flexibility may allow slight movement. A temporary restoration that binds on the prepared teeth and is slightly flexed at cementation may induce some movement as the material attempts to return to its original shape.

Obtaining a Plaster Index from the Working Cast

If only the cast is used, the parts are assembled using the facial index and luted in position with hot sticky wax (Fig. 16–2A). A final check of orientation and gap distance is then performed.

The relationship of the parts is recorded by letting a material flow over the castings that has the ability to form a rigid stable index. Impression plaster is one of the materials frequently used. Other materials can produce accurate indices, but plaster is less expensive, easier to handle and to control the flow of, and the residue left on the castings is easily removed. When plaster is used, a sufficiently large area of the castings must be covered by the index so that the parts can be accurately reoriented into the hardened index after it is removed. However, the material should not engage undercut areas, since this makes it difficult to remove the index from the castings, and produces potential damage to the index.

In order to control the extent of flow of the indexing material, undercut areas on the castings are blocked out with modeling clay or modeling dough, and a flat surface is produced around the perimeter of the castings (Fig. 16–2B). Posterior units usually require an occlusal index, whereas lingual and incisal surfaces are used for relating parts for anterior prostheses.

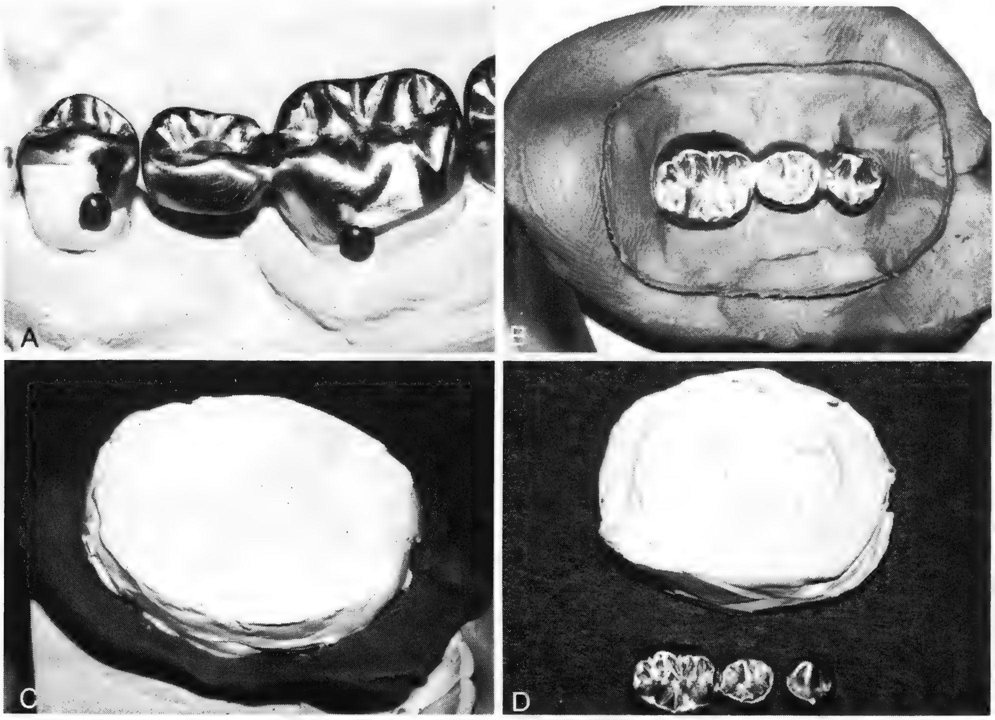


FIGURE 16–2 Obtaining a Plaster Index from the Working Cast

A, Castings held in position with sticky wax.
B, Modeling clay placed around castings to block out undercuts. Note the line scribed in clay to serve as a guide to the size of the index. Beeswax has been flowed into the gap between parts.
C, Plaster extended peripherally to scribe line.
D, Hardened index removed from cast.

Beeswax is made to flow into the connector areas to prevent the indexing material from entering.

Impression plaster is mixed and placed over the castings. The index should uniformly extend about 6 mm beyond the perimeter of the castings (Fig. 16–2C). After the index hardens, it is removed from the working cast (Fig. 16–2D).

Obtaining an Intraoral Plaster Index

The prosthesis parts are seated on the abutment teeth, and a wax tray is fabricated that is contoured to the arch (Fig. 16–3A). The tray should extend one tooth beyond each end of the prosthesis and project about 6 mm facially and lingually beyond the perimeter of the parts. Impression plaster is mixed to a thick consistency and placed inside the carrier, and a spatula is used to smooth the surface of the plaster. The plaster is then centered and seated over the castings and held without movement until it hardens (Fig. 16–3B). The tray and castings are then removed from the mouth (Fig. 16–3C). The use of a thick mix of plaster and delaying placement over the castings until the plaster just begins to stiffen reduces the time that the index must be held in the mouth. A section from a metal or plastic impression tray can also be used to contain the plaster and carry it to the mouth.

One difficulty that may be encountered is in keeping the retainers completely seated. If they tend to become unseated, temporary cement is used to lute the castings to the prepared teeth. Only a small amount of cement should be used, and it should be restricted to the area near the margin. Otherwise, subsequent removal of the castings from the teeth may be difficult.

Another difficult aspect of an intraoral index is the inability to block out undercut areas on the castings and to produce a flat surface around the perimeter. For this reason, it is best to place the indexing plaster over the castings in a manner that does not cause it to extend into undercut areas. This is best accomplished by using a relatively thick mix of plaster that is contained within a carrying device. Controlling the pressure that is exerted when the plaster is seated over the castings limits the area that is covered.

PREPARATION FOR INVESTING

When the index is removed from the mouth or the working cast, the parts may either stay on the prepared teeth or remain attached to the index. Any units that remain in the plaster should be removed because they may have been partly dislodged and now may not be fully seated in the index. Also, if the castings are firmly locked in plaster and not separated prior to investing, the soldering investment may fracture when the index is later removed.

After the castings have been removed, the index is trimmed with a sharp knife or scalpel to provide the proper dimensions to the soldering investment assembly. About 6 mm of plaster should surround the castings. The index is also trimmed at the periphery of each tooth indentation to remove any sharp fragile projections of plaster that could easily break off and fall under the castings as they are repositioned. The index must be meticulously cleaned of any loose debris that could interfere with accurate orientation of the parts.

The castings are reseated into the index, held in position by a finger or metal instrument, and hot sticky wax is made to flow at the junction of the castings and plaster (Fig. 16–4A, B, C). The parts should be held in position until the wax hardens.

The soldering investment must be able to engage the castings so they are securely locked into the set investment. With certain pontics, a portion of the sprue must

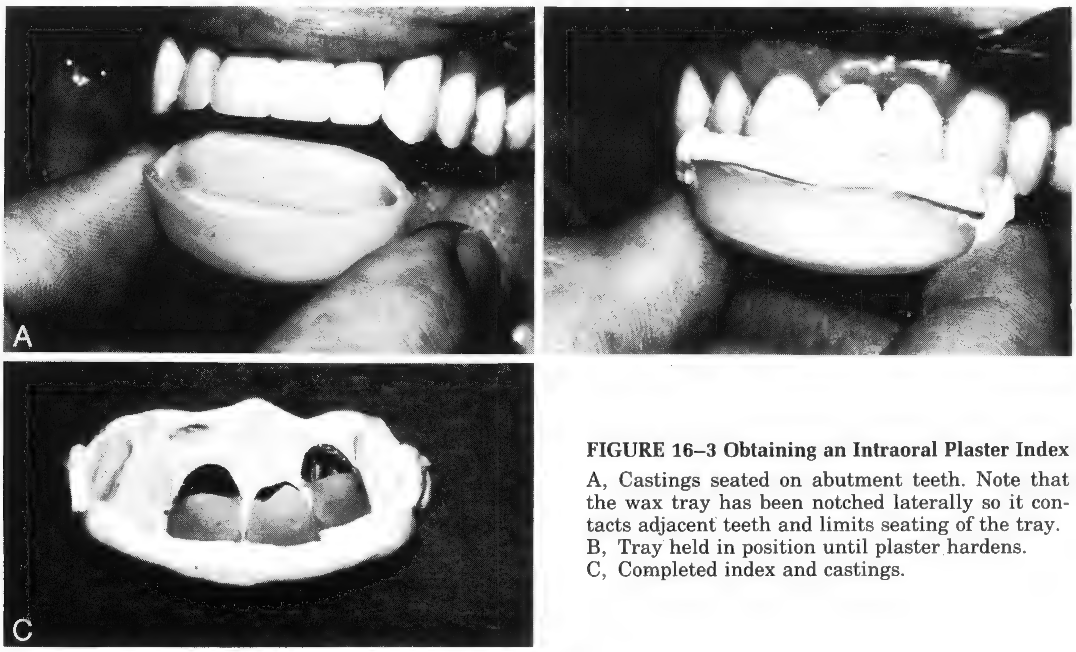


FIGURE 16–3 Obtaining an Intraoral Plaster Index

A, Castings seated on abutment teeth. Note that the wax tray has been notched laterally so it contacts adjacent teeth and limits seating of the tray.
B, Tray held in position until plaster hardens.
C, Completed index and castings.

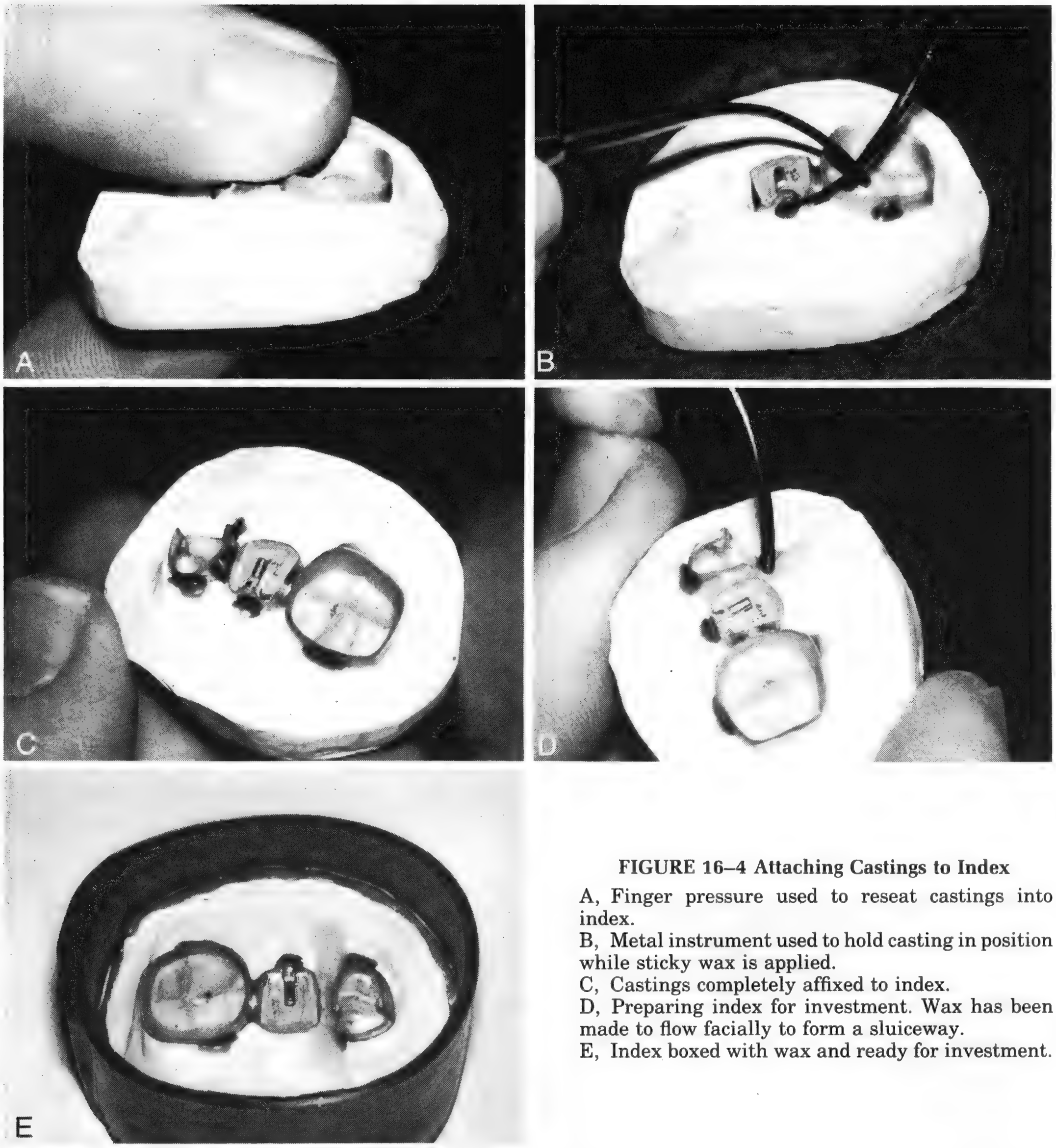


FIGURE 16–4 Attaching Castings to Index

A, Finger pressure used to reseat castings into index.
B, Metal instrument used to hold casting in position while sticky wax is applied.
C, Castings completely affixed to index.
D, Preparing index for investment. Wax has been made to flow facially to form a sluiceway.
E, Index boxed with wax and ready for investment.

be left on the casting so the investment can grasp the pontic and prevent its dislodgment from the soldering assembly during handling. An alternative to leaving a section of the sprue is to attach a wax rod at a more convenient area of the pattern, which is left on the casting until the assembly is completed.

Beeswax is made to flow into the connector area to prevent soldering investment from flowing into the gap between the parts. The amount of wax added should be slightly greater than the desired size of the solder joint.

Wax is also added facially and lingually, in a triangular form, to the connector areas in order to produce sluiceways in the soldering assembly (Fig. 16–4D). This facilitates passing the soldering flame around and through the joint area.

Resin separating medium* is applied to any exposed plaster to prevent the soldering investment from adhering to the index. A thin strip of wax is placed around the periphery of the index to produce a box that can contain the soldering investment (Fig. 16–4E).

*Al-cote, L. D. Caulk Company, Milford, DE 19963.

SOLDERING INVESTMENTS

The composition of the soldering investment is similar to that of a quartz casting investment. In fact, the stronger casting investments can sometimes be used as soldering investments. An investment containing quartz is preferable to a cristobalite investment because of the lower thermal expansion of the former.

Furthermore, an investment with a low normal setting expansion is preferred to one with a high setting expansion. The setting expansion tends to change the spacing of the parts and may even cause warpage. Under

no circumstances should the investment come in contact with water during setting because this causes a hygroscopic setting expansion.

A third requisite of a soldering investment is that it withstand the heat of the flame during soldering without cracking.

FORMING THE SOLDERING ASSEMBLY

Soldering investment* is mixed to the proper thick consistency and placed inside and around the castings with a small instrument or brush, with care being taken not to trap air (Fig. 16–5A, B). A spatula is then used to add additional investment until there is about 12 mm of investment above the casting margins (Fig. 16–5C). Vibrating the investment into the index is to be avoided, since this may result in partially dislodging the castings from the index.

After the investment sets, the index is removed, and the bulk of the wax is removed with an instrument (Fig. 16–6A, B). The soldering assembly is then placed in boiling water or chloroform to remove the remaining wax and leave clean metal surfaces onto which the solder readily flows (Fig. 16–6C). The joint area should be inspected for the presence of loose investment particles or other debris. If foreign material is observed, unwaxed dental floss or compressed air can be used to clean the joint area.

*Soldering Investment, Whip-Mix Corporation, Louisville, KY 40217.

SOLDERS, FLUX, AND ANTIFLUX

Before discussing some of the materials used to form the solder joint, it is important to define the process. *Soldering* is the joining of metals by the use of a filler metal that has a substantially lower fusion temperature than that of the metal parts being joined. The process involves the melting and flowing of the filler metal, or solder, by capillary action between and around the parts to be joined. The solder depends on wetting for the bond formation, and neither diffusion nor melting of the metal assembly is required to achieve primary metallic bonding.

It may also be advisable to summarize the events that occur during soldering. First, a flux is applied to the metal surfaces to be united. Upon heating, the molten flux displaces the atmospheric gas layer on the metal surfaces and removes tarnish films. The solder then displaces the molten flux, wets the metal, and forms a solder-metal interface, thus bonding and establishing a metallic continuity through the joint.

FLUXES

The Latin word "flux" means flow. In soldering, fluxes are used to dissolve surface impurities and protect the surface from oxidation during heating. Tarnish films react chemically with the flux by either (1) combining with a component of the flux to form a third compound that is soluble in the flux or (2) being reduced to a tarnish-free alloy.

Several high temperature melting salts, notably borax or boric acid, can be used individually as fluxes. Silica

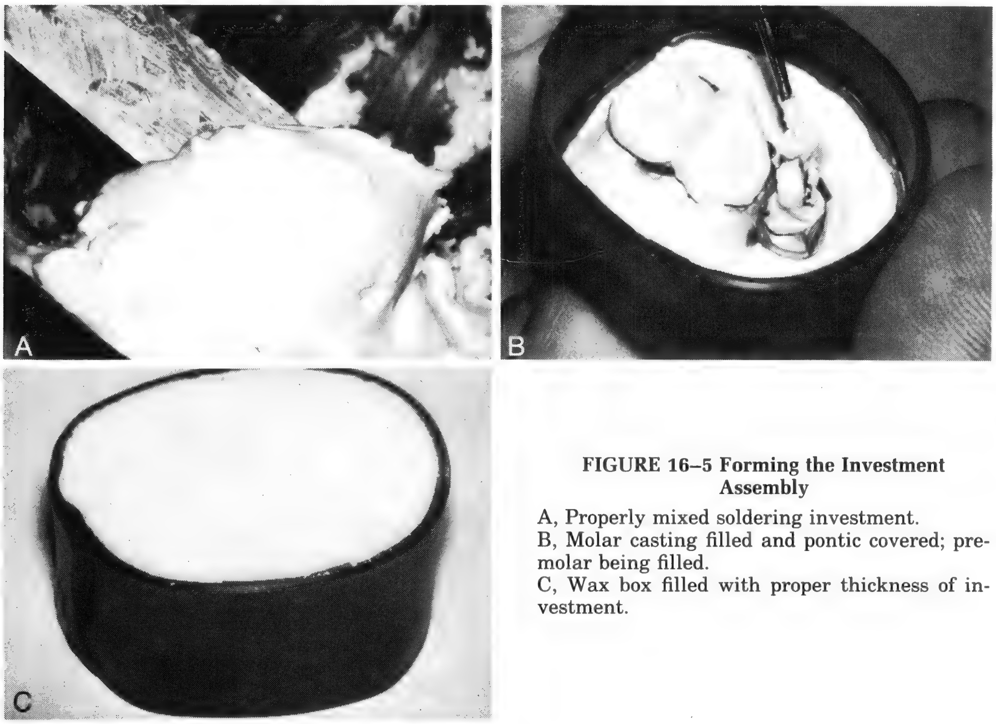


FIGURE 16–5 Forming the Investment Assembly

A, Properly mixed soldering investment.
B, Molar casting filled and pontic covered; premolar being filled.
C, Wax box filled with proper thickness of investment.

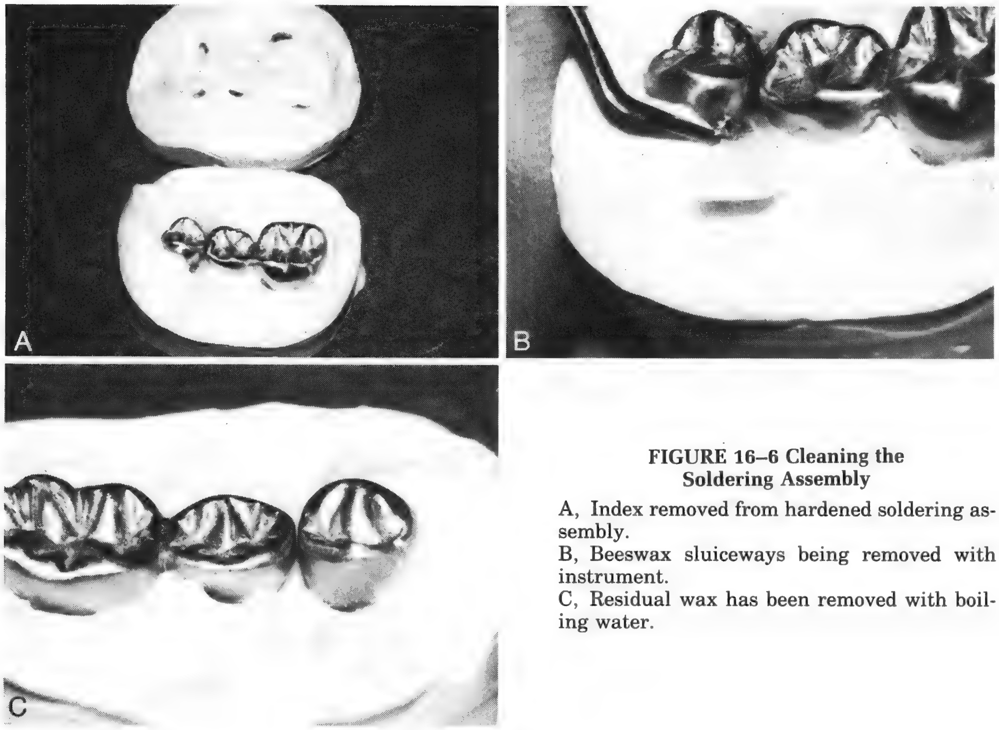


FIGURE 16–6 Cleaning the Soldering Assembly

A, Index removed from hardened soldering assembly.
B, Beeswax sluiceways being removed with instrument.
C, Residual wax has been removed with boiling water.

is also generally added, since it contributes to the toughness of the film after melting so that it stays in place. However, because each chemical of this type exhibits certain fluxing characteristics of its own, they are usually combined so that a superior flux can be produced with the good characteristics of each of the ingredients. The flux can be employed in a powdered form or as a paste. If it is applied as a paste, alcohol should be used as the liquid agent rather than water. A paste formed by mixing fused borax in water results in a hydration of the sodium pyroborate to common borax, and the resulting efflorescence is troublesome.

One highly successful method for forming a paste is to mix the powdered flux with an inert grease or plastic gel such as petrolatum. The grease protects the flux from the air, and when the organic petrolatum is fused on the metal with the flux, it carbonizes and is eliminated into the air or flame.

An *antiflux* is any material that is placed on the work, before the soldering flux is applied, to confine the flow of the molten solder. If the soldering temperature is not too high, the area can be marked off with a lead pencil. The molten solder does not flow across the graphite line, unless a temperature is reached at which the carbon combines with the oxygen and thus is removed from the surface.

Requisites for a Dental Solder

Dental solders are classified metallurgically as *hard solders* in contrast to the low-melting *soft solders* used by plumbers and tinsmiths. The hard solders are generally high-fusing, more resistant to tarnish, and stronger than the soft solders.

The following general properties are important in a hard dental solder:

1. First, a dental solder must have resistance to tarnish and corrosion in the oral fluids.
2. The fusion range of the solder must be lower than that of the parts to be soldered so that the parts do not melt. This factor is controlled by the composition of the solder. The fusion temperature of the solder is often at least 100° C (180° F) below the fusion temperature of the work, although technicians expert in the art often join parts with solders possessing a fusion temperature 50° C (90° F) or less below that of the work.
3. The composition of the solder should be such that it is free-flowing, that is, it flows readily after it melts. A freely flowing solder spreads easily and quickly over clean metal surfaces; it penetrates small openings and follows points of contact by capillary action.
4. The solder should not cause pitting of the soldered joint. Unfortunately, pitting is one of the most prevalent flaws encountered in soldering procedures, and it is usually the result of improper technique. However, pits may be more prevalent when solder is used that contains a considerable amount of base metal. On overheating, the base metals volatilize, and the vapor creates pits.
5. The strength of the solder should be at least as great as that of the parts to be soldered.
6. The color of the solder should match that of the parts to be soldered. However, after a soldered joint has been polished, it usually is not noticeable, although there may be considerable difference in color between the solder and the work, provided that the proper soldering technique has been employed.

Composition of Solders

The basic composition of gold solder is similar to that of a casting alloy, namely gold, silver, and copper. Zinc and tin are added to reduce the fusion temperature of the solders because the addition of copper is not sufficient for this purpose.

In addition to the base metals, phosphorus may be added in a small amount as a deoxidizer to improve the resistance of the solder to oxidation during fusing.

The higher the silver content, the more narrow is the melting range, the greater is the adherence of the solder to the metal, and the more free-flowing is the solder. Conversely, when a considerable amount of copper is added at the expense of the silver, the fusion range is increased to such a degree that only partial melting of the solder may occur and the solder penetrates the parts to be soldered instead of flowing.

The gold composition of the solder is properly designated by its fineness. Fineness of 1.000 is pure gold. On this basis 0.750 fine would be 750 parts gold and 250 parts other metals. Gold manufacturers, however, may designate their solders as 14-karat, 18-karat, and so forth. Such a designation does not indicate the gold content of the solder but rather the karat of the gold alloy on which the solder is intended to be used. For example, an 18-karat solder does not contain 18 parts in 24 parts of pure gold; rather, it is a solder to be used with a gold alloy of 18 karat. With modern dental alloys, which may contain platinum and palladium in addition to the gold, such a designation is meaningless because the melting point and other properties are altered by the additions.

Fusion Temperature

It is desirable that the fusion temperature of different solders vary progressively from a low temperature to a high temperature. Occasionally, in the construction of complicated dental prostheses, it is necessary to solder one part to another part that has already been soldered. Then, a solder with a lower fusion temperature than the first one used is necessary. A third soldering procedure may be required, and a solder with a still lower fusion temperature must be used, and so on. It is possible to formulate satisfactory dental solders with graded fusion temperatures if the proper proportions of the constituent metals are employed.

The minimal information required in the selection of a dental gold alloy would include:

1. The lower limit of the melting range of the alloy being soldered
2. The upper and lower limits of the melting range of the solder
3. The fineness of the solder

The melting range limits provide an indication of the silver-copper ratio and whether the solder flows and wets well or just builds up and penetrates the parent alloy. The fineness, of course, influences the corrosion resistance and strength of the alloy.

Microstructure of the Soldered Joint

The union of the solder with the parts joined is the result of adhesion by primary (metallic) bonding. However, overheating or prolonged heating may lead to diffusion of the solder and the formation of new alloys at the solder-work interface. Such a process would contribute to the chemical inhomogeneity of the materials and a reduction in the strength and quality of the joint.

No diffusion of the solder into the alloy occurs in the properly heated joint, and there is a well-defined boundary between solder and soldered parts.

The same effect, diffusion of the solder, can occur at lower temperatures, although not as readily, if the heating time is prolonged. Therefore, soldering should be accomplished at the lowest temperature and in the least time possible.

Maximal strength is attained if the prosthesis is cooled slowly in the investment for 5 to 7 minutes before it is quenched. If it is allowed to cool slowly to room temperature, there is a tendency for excessive brittleness to develop in the joint.

It is possible that the grains in the soldered part may act as nuclei of crystallization for the solder. Thus, the microstructure of the solder tends to match that of the casting with which it is in contact during solidification. This is advantageous in that a more homogeneous microstructure is created for the joint. Also, when the fine-grain castings are soldered together, the physical properties and corrosion resistance of the joint may be improved as the solder assumes a fine-grain structure.

Probably the factor having the greatest effect on the strength of a soldered joint is the presence of porosity in the solder after solidification. Improper cleaning, fluxing, spacing of the parts, or application of the flame may cause porosity, as does overheating. In addition to the porosity caused by volatilization of base metals, the borax flux may fuse with the metal and prevent the solder from flowing over the surface. Placing the solder in the joint before heating produces more porosity than if the solder is applied after heating the work.

SOLDERING TECHNIQUE

A small amount of soldering flux* is applied to the joint area, and the assembly is placed in a room-temperature burnout furnace (Fig. 16–7). The furnace is set for 427° C (800° F), and the soldering assembly is heated

*Soldering flux paste, J. M. Ney Company, Bloomfield, CT 06002.

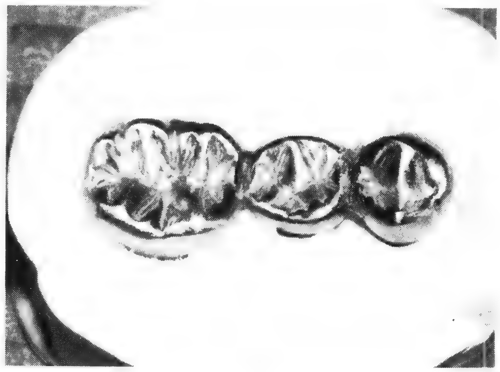


FIGURE 16–7 Soldering flux applied to connector area prior to placing assembly in furnace.

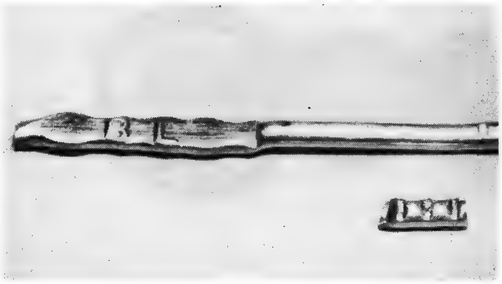


FIGURE 16–8 Solder strip cut so a segment three notches long is available to produce adequately sized solder joint.

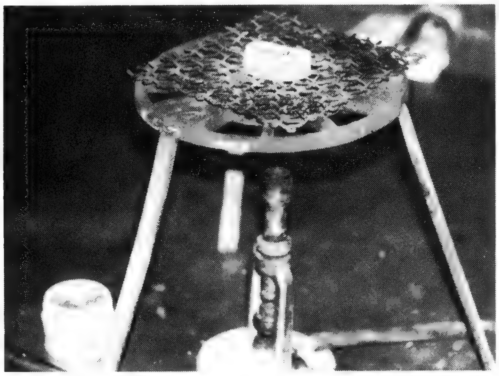


FIGURE 16–9 Soldering assembly placed on tripod stand over Bunsen burner flame.

slowly to this temperature. This procedure provides uniform drying and preheating of the assembly. If the temperature is carried above 538° C (1000° F), there may be enough oxidation of the alloy to interfere with subsequent flow of the solder.

A piece of solder is cut to produce the desired joint size and set aside (Fig. 16–8). The amount of solder needed depends on the proximal contour of the adjoining casting, the amount of space between the parts, and the desired joint size.

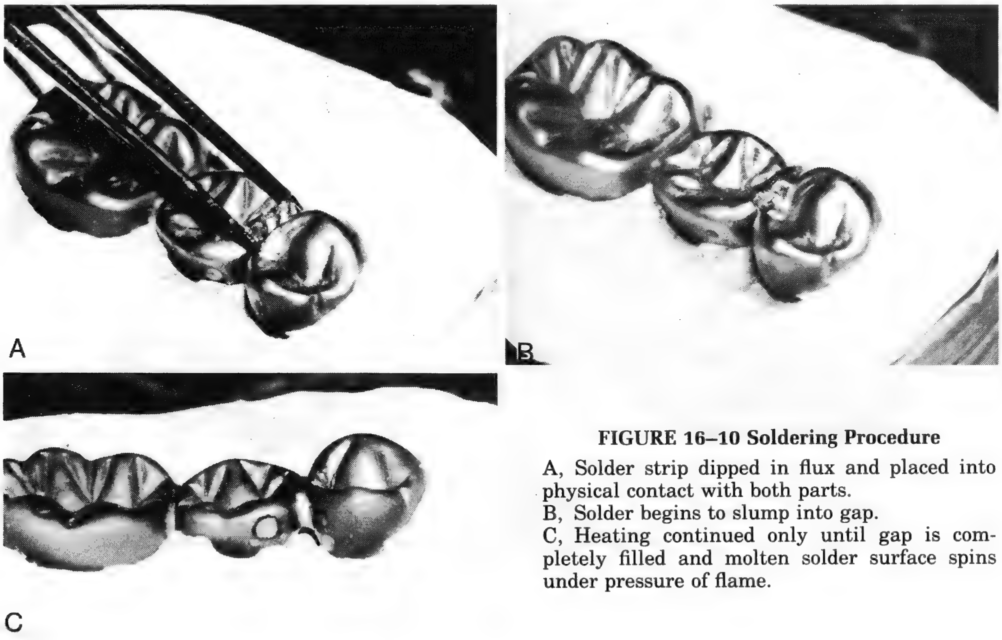
The proper setup for soldering includes the solder, flux, Bunsen burner with wire mesh stand, soldering tweezers, and gas-air torch.

The heated assembly is removed from the oven and placed on the wire mesh stand over the Bunsen burner flame (Fig. 16–9). The torch flame is used to heat the assembly from above with the Bunsen burner flame heating from below. To ensure gradual heating, a brush-type flame is used first, and then the torch is adjusted to produce a hotter flame with a definite inner reducing zone. The torch is continuously moved around the assembly to provide uniform heating of the investment. Failure to apply heat uniformly results in distortion of the assembly and a prosthesis that does not fit.

The assembly is heated until the castings exhibit a reddish glow immediately after the flame is removed. The tip of the reducing inner cone is focused on the joint area to prevent oxidation that impedes solder flow. The solder is picked up with the tweezers, dipped into the flux, and placed into the joint area so that there is physical contact with both parts to be joined (Fig. 16–10A). The heating is continued until the solder melts and flows into the joint area (Fig. 16–10B, C). When the joint is filled, the surface of the molten solder spins from the force of the flame. Prolonged heating beyond this point results in a porous and weak solder joint.

Each joint is soldered in turn, and the assembly is allowed to cool for 5 to 7 minutes. Rapid quenching of a soldered bridge does not permit proper hardening of the metal and may produce distortion.

After cooling, the assembly is immersed in water, which weakens the investment, allowing it to be readily fractured away from the castings. Investment retained inside the castings is removed with a small metal instrument.



A

B

C

FIGURE 16–10 Soldering Procedure

A, Solder strip dipped in flux and placed into physical contact with both parts.
B, Solder begins to slump into gap.
C, Heating continued only until gap is completely filled and molten solder surface spins under pressure of flame.

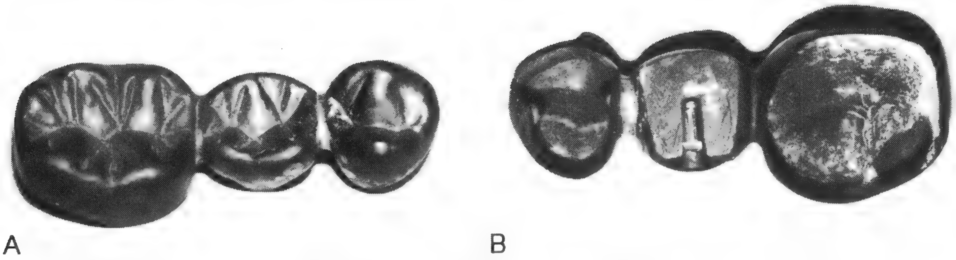


FIGURE 16–11 Inspection of Connection

A, Occlusal view of devested prosthesis showing complete and pit-free connector.
B, Cervical view of solder joint.

INSPECTION OF THE CONNECTORS

The solder joints should be carefully inspected to determine whether they are complete and without surface pits or voids (Fig. 16–11). Ultrasonic cleaning of the prosthesis in detergent completes the removal of residual investment particles. Oxide removal is then accomplished in a suitable pickling solution.*

Soldering of base metal alloys is discussed in Chapter 23.

If the connectors have the proper form, size, and integrity, an attempt should be made to fracture the joint by firm manual force. Any joint that distorts or fractures is either defective or exceptionally small. Either situation would cause a clinical failure, and early detection saves considerable time and aggravation.

TRIAL SEATING ON WORKING CAST AND FINISHING

The prosthesis is seated on the working cast to test the accuracy achieved during the soldering procedure. If it is assumed that there are no undercuts between abutment preparations, complete seating of the prosthesis should be possible with only light finger pressure. The retainers should exhibit the same high quality of marginal adaptation present prior to soldering (Fig. 16–12), and the pontic should possess the same relationship to the edentulous ridge.

Occlusal adjustments are then completed, and all the casting surfaces and margins are polished (Fig. 16–13).

The connectors must be well polished, exhibit no roughness or pits, possess the proper dimensions, and have a concave form. A very small round bur (number 1/4 or 1/2) can be used to refine the form of the joint and reduce an overly large connector (Fig. 16–14). Particular emphasis must be placed on the smoothness of the cervical aspect that will be in proximity to the gingiva. Access to this area is more difficult and requires instruments that achieve contact without disturbing the proximal contours or the margins of the retainers. The edge of a thin rubber wheel* or paper disc† can be effectively used to smooth the transition from casting to solder and polish the cervical aspect of the connector (Fig. 16–14). Care must be taken that these instruments do not contact the margin of the restoration.

Bristle brushes‡ are used with tripoli and rouge to achieve the final smoothness and lustre. Rag wheels and chamois wheels are also beneficial for use with rouge.

*Jel-pac, J.F. Jelenko Company, Armonk, NY 10504.

*Brownie Rubber Wheels, Shofu, Menlo Park, CA 94025.
†Medium Cuttle Disc, E. C. Moore Company, Dearborn, MI 48126.
‡Abbott-Robinson bristle brushes (#11 soft), Buffalo Dental, Brooklyn, NY 11207.

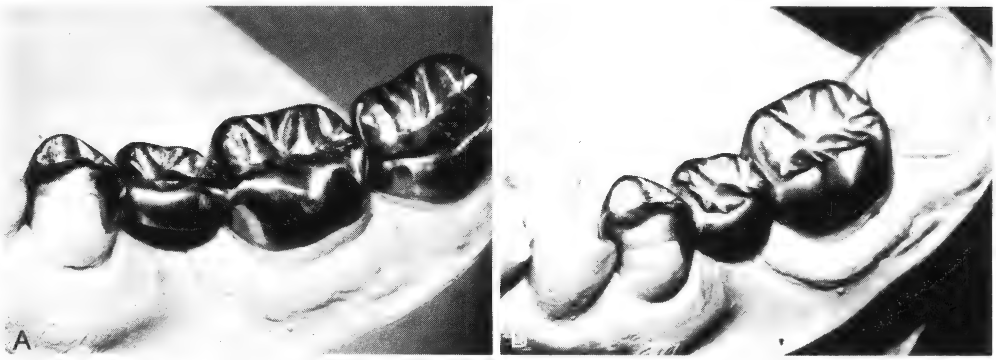


FIGURE 16–12 Evaluation of Prosthesis Fit After Soldering

A, Fit of parts prior to soldering.
B, Fit of prosthesis after soldering.

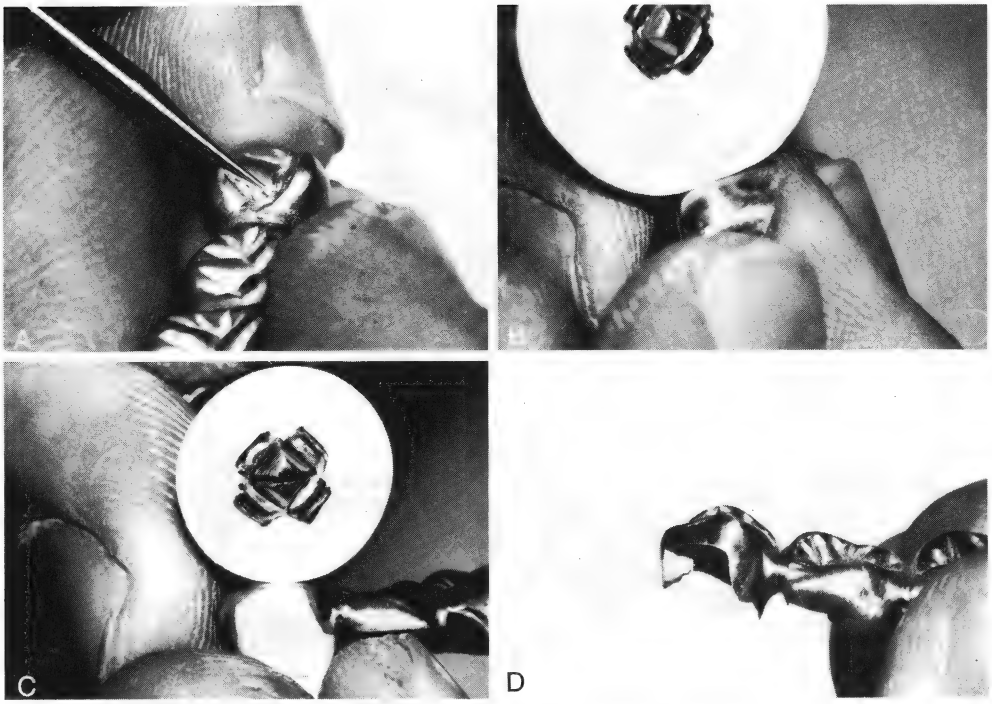


FIGURE 16–13 Occlusal, Axial, and Marginal Polishing

A, Occlusal surface refined with 33½ inverted cone bur.
B, Axial surfaces being polished with cuttle disc.
C, Margins being polished on die using fine cuttle disc.
D, Surface texture after initial finishing steps with discs.

The prosthesis is positioned so the casting margin adjacent to the joint is held indented into a finger or thumb to prevent excessive polishing that could round off the casting margin (Fig. 16–15). Completely polished restorations should exhibit very smooth surfaces without observable ripples when light reflects off their surfaces. The occlusal grooves and fossae should also be smooth and readily cleanable (Fig. 16–16).

SOLDERING DEFECTS AND CORRECTIONS

The Prosthesis that Fails to Fit

When the restoration fails to seat on the working cast, it must be disassembled and resoldered. This problem can be caused by many factors, such as failure to maintain the proper relationship of the parts, improper heating of the assembly, or an improper proximal gap. If the gap relationship is at fault, this must be corrected prior to resoldering by contour adjustments or the fabrication of new castings.

The decision to disassemble should not be made until the restoration and working cast are carefully checked for the presence of foreign materials (such as investment or stone) that prevent proper seating.

A decision must be made regarding which solder joints are to be broken. A critical analysis of the fit of each retainer and the relationship of the pontic to the edentulous ridge generally helps determine whether one or all of the connectors must be separated.

A prosthesis can be disassembled by cutting the joint with a thin separating or diamond disc until it is small enough to be fractured manually. Care must be used with this process to avoid an excessively large gap between the parts.

Disassembly also can be accomplished by heating the solder joint until it can be torn. This is a safe procedure that does not produce loss of proximal form or an excessively large gap between the parts. It is preferable in most cases to cutting of the joint. This technique requires a Bunsen burner with a small pointed inner cone and two pairs of cotton pliers or similar instruments for grasping the parts. The retainer adjacent to the defective joint is grasped with one pair of pliers, and the pontic is held with the other pair. Thin marginal areas that are susceptible to distortion should not be grasped by the pliers. The prosthesis is held so that the tip of the blue inner cone of the Bunsen burner flame is directly in contact with the solder joint. The heating is continued until the castings exhibit a slight reddish glow immediately after the restoration is removed from the flame. Continued heating while a force is applied to pull the castings apart results in tearing of the solder (Fig. 16–17). This occurs before the solder flows, since it becomes very weak at a point just below its fusion temperature.

The pliers grasping the pontic act as a heat sink,

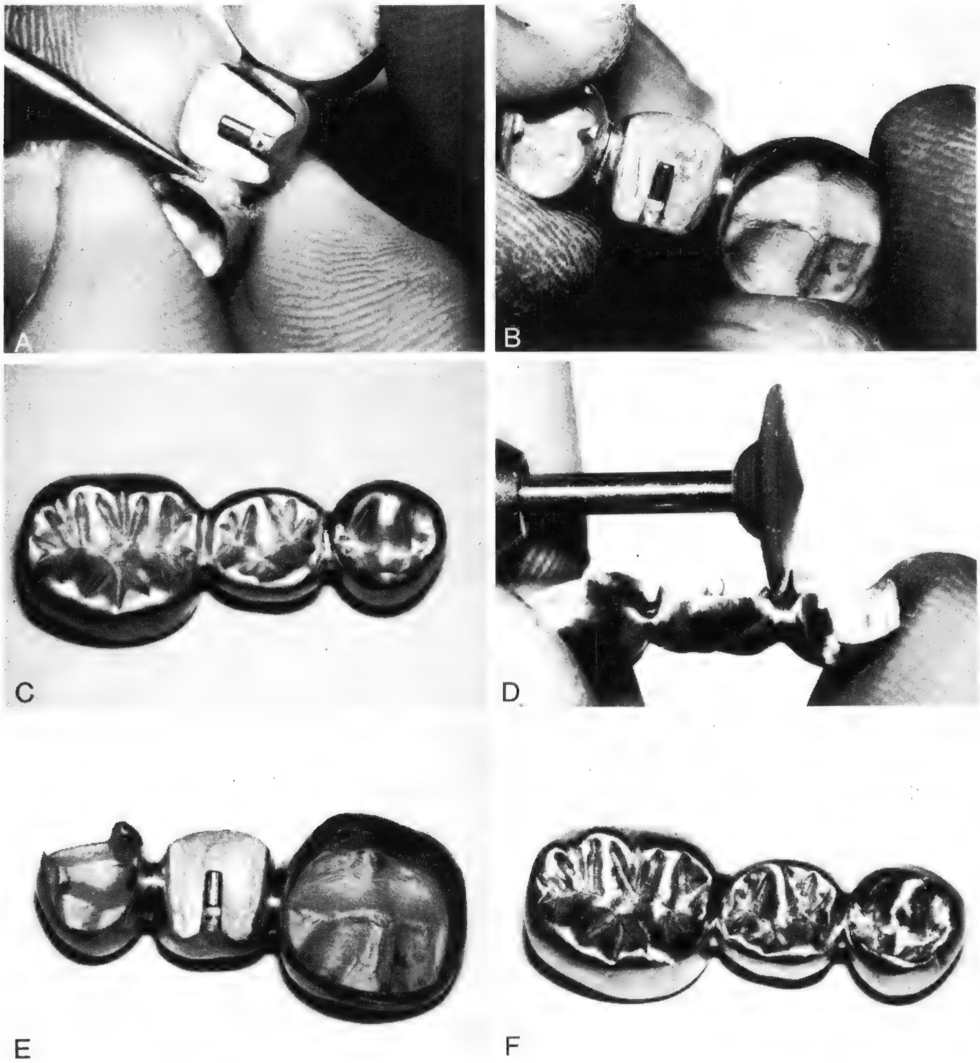


FIGURE 16–14 Connector Refinement and Polishing

A, Number ½ round bur used to refine and smooth cervical aspect of connector.
B, Cervical view of connector after refinement.
C, Occlusal view of connector after refinement.
D, Rubber wheel used to polish cervical aspect of connector.
E, Connectors polished cervically.
F, Occlusal view of polished connectors.

which draws heat from the pontic and prevents the other joints from being disturbed. In this manner, one or all of the solder joints can be separated individually. Disassembly of a prosthesis with metal-ceramic parts is handled differently and is discussed in Chapter 23.

After the parts have been separated, they can be quenched in water, pickled to remove the oxides formed in heating, and reassembled on the working cast. Projections of torn solder generally interfere with normal proximal relationship of the parts, and some reshaping with abrasive discs is necessary to reestablish the correct gap relationship.

The parts are reassembled in soldering investment and resoldered as usual.

Lack of Integrity

Soldered joints with pits or voids are not acceptable. If the defects are small and affect only the surface, reshaping may be possible. However, the final size of the joint must be such that a dimensional decrease still leaves adequate bulk of solder for strength.

A joint is unacceptable when it possesses a large void or has internal porosity that continues to be exposed during the finishing and polishing process (Fig. 16–18). Either of these problems must be corrected by reinvesting the prosthesis and reflowing the joint to achieve proper integrity and strength.

When the restoration fits properly but a defective

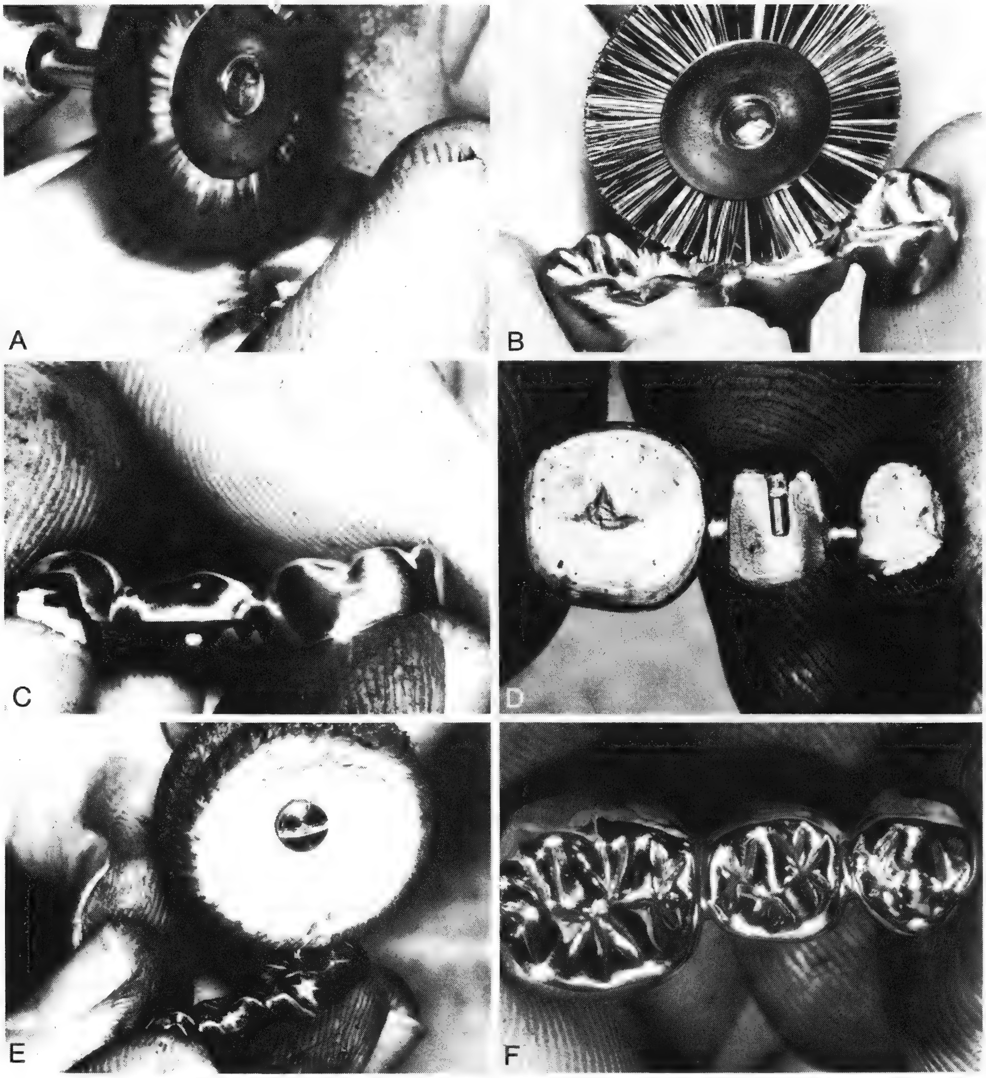


FIGURE 16–15 Final Lustre Using Tripoli and Rouge

A, Bristle brush and tripoli used to polish axial surfaces. Note that the margin is embedded in the thumb for protection.
B, Bristles fitting into occlusal grooves.
C, Surface lustre after use of tripoli.
D, Cervical aspect of connectors after using tripoli. Note the uniform smoothness and absence of irregularities.
E, Rouge being applied with leather chamois wheel.
F, Surface lustre after use of rouge.

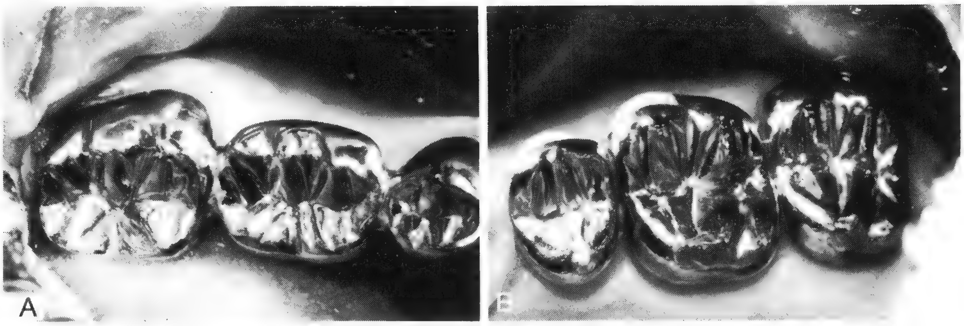


FIGURE 16–16 Appearance of Polished Grooves and Fossae

A, Occlusal view of mandibular prosthesis with smooth yet well-defined grooves and fossae.
B, Occlusal view of three single restorations with distinct occlusal grooves that are well polished.

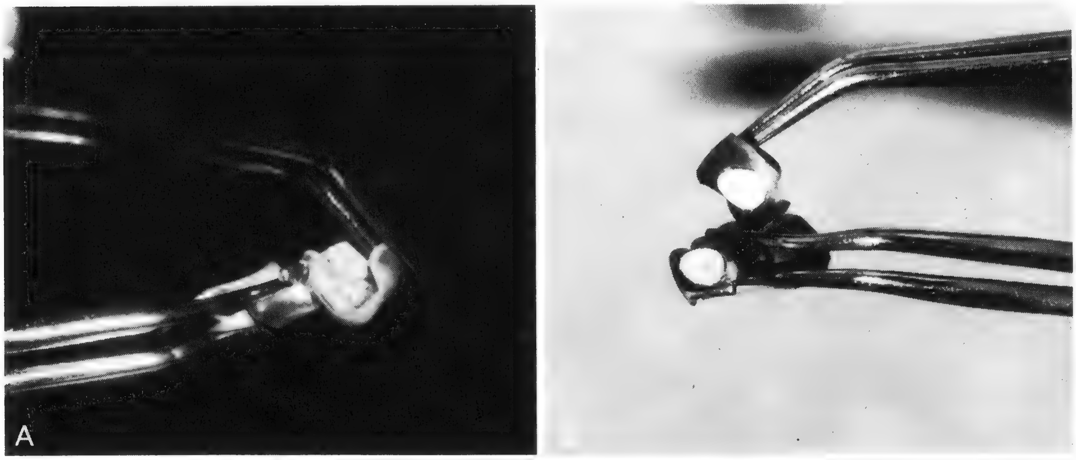


FIGURE 16–17 Breaking a Solder Joint

A, Cotton pliers holding castings on both sides of a defective joint. Inner cone of Bunsen burner flame is held on connector area, while a continual force is applied to pull the prosthesis apart.
B, Separated prosthesis. The connector tears before the solder completely reflows.

joint requires correction, the restoration usually can be placed into soldering investment without the defective connector being broken. The joint should be thoroughly cleaned and a bead of beeswax flowed around the joint, with facial and lingual wax extensions made to provide access with the flame. The prosthesis is then set into a wax box filled with mixed soldering investment. The soldering procedure is handled as usual and the solder made to flow. A small amount of new solder should be added when a defective joint is reflowed in order to achieve proper joint size and quality.

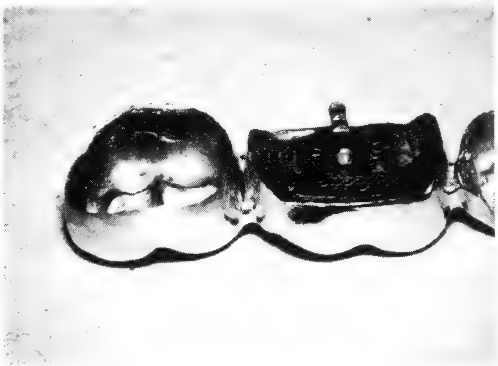


FIGURE 16–18 Soldered prosthesis with defective joint. Connector between pontic and molar is incomplete. The other connector is small and rough.

Poor Size or Form

If the prosthesis seats properly but the connections do not have adequate dimensions for strength (Fig. 16–18), the prosthesis is placed directly into the investment and additional solder is added. An overly large joint that interferes with effective oral hygiene can usually be corrected by grinding away the excess material.

Occasionally, the presence of excess cervical solder is related to the form of the parts. Solder flows toward the most convex portion of the proximal surfaces in which the parts are closest together. If the castings are shaped with the proximal convexity located too far cervically, the result is a joint that impinges on the cervical embrasure space. It may not be possible to correct the defect by grinding, since removal of the cervical excess creates a joint that is too small, and the addition of

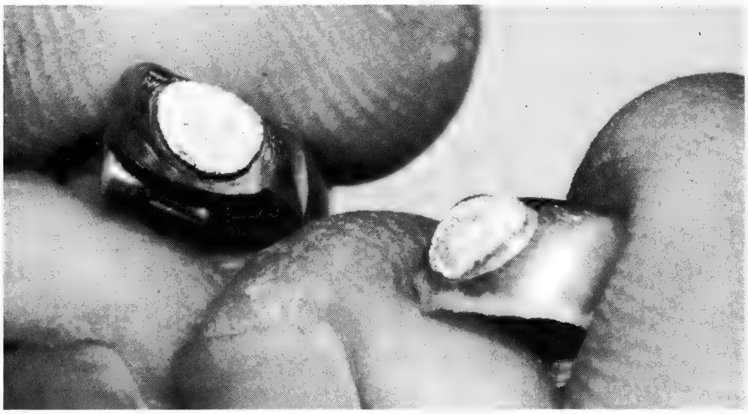


FIGURE 16–19 A defective joint that fractured shows numerous pits and voids.

solder results in a return to the original form. This situation may only be solved by separating the prosthesis, recontouring or remaking the parts, and then reassembling them.

Foreign Body Inclusion

Any foreign material such as soldering investment that is trapped in a joint must be removed. If there is adequate overall connector dimension, this can be accomplished by grinding away the foreign material and polishing the affected area.

If grinding results in an undersized connector, the restoration must be reinvested after all foreign material has been removed and additional solder added.

Joint Fracture During Testing

Occasionally, manual force applied to a normally sized solder joint causes fracture. This problem is most often related to joint porosity resulting from improper soldering technique (Fig. 16–19). The joint is resoldered after the rough torn connector has been smoothed.

17

Clinical Evaluation, Adjustment, Cements, and Cementation

Prior to cementation, the assembled prosthesis is seated on the prepared teeth for final evaluation. The same items that were appraised and modified on the working cast are clinically critiqued and adjusted if necessary.

Generally, local anesthesia should be administered to prevent soft tissue and pulpal sensitivity during removal of the temporary cement, drying of the tooth surfaces, and other cementation procedures. However, older patients with considerable secondary dentin formation may not need anesthesia.

Prior to the insertion of any casting, the tooth must be completely clean and free of all foreign material (Fig. 17–1). A debris layer may be present as a remnant film from the temporary cement. All cavity preparations have a "smear layer" that is produced by the instrumentation. This debris must be removed in order to produce mechanical bonding, or in the case of a polyacrylic-acid–based cement (such as polycarboxylate or glass ionomer), adhesion to the calcium present in the enamel and dentin. The tooth surfaces can be cleansed using a pumice wash or commercially prepared agents or by swabbing the surfaces with moistened cotton pellets. Pumicing the preparation with a slurry, not a paste, is more effective in removing the debris than simply flushing the surface with water. If a polycarboxylate or glass ionomer cement is to be used, swabbing of the surface for 15 seconds with a solution of polyacrylic acid, that is, the liquid supplied with a polycarboxylate cement,* is particularly useful. Regardless of the method used, it is extremely important that the preparation be thoroughly cleansed. After cleaning, the tooth is dried with compressed air in order to critically evaluate the cleanliness.

PROXIMAL CONTACTS

Castings should completely seat on prepared teeth with the application of finger pressure. Failure of a restoration to fully seat can be the result of unduly tight proximal contacts (Fig. 17–2). To determine whether

*Durelon, Premier Company, Philadelphia, PA 19107

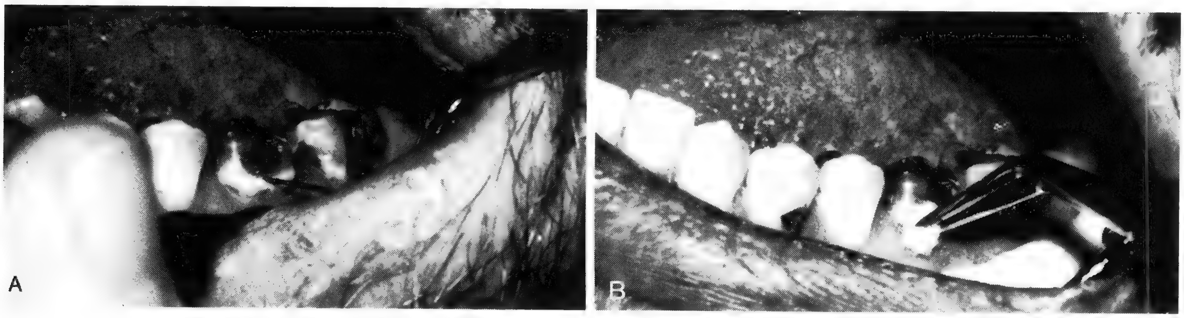


FIGURE 17–1

A, Particles of residual temporary cement being removed with explorer tip.
B, Preparation being swabbed with moistened cotton pellet.

FIGURE 17–2 Full crown that fails to seat owing to heavy proximal contacts.

FIGURE 17–4 Occlusal registration strip between restoration and adjacent tooth.

heavy contact exists, the restoration is positioned to the point at which reasonable finger pressure no longer produces further seating. To force the casting beyond this point by such means as biting pressure is contraindicated, since the restoration may wedge between adjacent teeth and make removal extremely difficult without damage to the tooth or restoration. If the restoration is fully seated, as evidenced by good marginal fit, an attempt is made to pass thin unwaxed dental floss through each proximal contact. A properly adjusted contact allows floss to snap through with resistance but without tearing (Fig. 17–3). Testing of other unrestored proximal contact areas with unwaxed floss identifies the proper degree of resistance desired. Removal of the floss by pulling it facially out of the embrasure rather than snapping it back through the contact is recommended to prevent unexpected dislodgment of the restoration. Also, the casting and fingers should be dry during insertion and removal of the restoration to help prevent inadvertent dropping. Restorations have been swallowed or damaged on the floor in this manner. Thin occlusal registration strips* (shim stock) can also be used to evaluate the strength of proximal contact (Fig. 17–4). These strips possess a thickness of approximately 12 μm.

A contact area that does not allow floss to pass through is adjusted until the proper pressure is exerted. This requires removal of the prosthesis from the mouth and adjustment of the contact area with a fine paper disc or an abrasive rubber wheel. Difficulty is sometimes encountered in locating the actual area of contact on the proximal surface. Thin articulating ribbon or paper can be placed in the area, and by seating the restoration the contact area is marked. A rubber wheel can be used to reduce the metallic gloss. Then a proximal burnish mark is formed upon seating (Fig. 17–5). Pressure-blasting the surface with fine-grit aluminum oxide produces a mat finish that is obviously burnished by contact with adjacent teeth.

Several trial seatings and careful adjustments are generally necessary to achieve the proper degree of proximal contact. If too much metal is removed, solder must be added to the deficient area, as described in Chapter 15.

It is possible to develop correct pressure on adjacent teeth and still experience tearing of the floss. This can be caused by rough surfaces on adjacent restorations or enamel created during tooth preparation. These areas should have been refined before the impression was obtained, since adjustment after the castings have been fabricated can produce open proximal contacts. Although an open contact may occur, any rough proximal areas discovered at cementation must be smoothed to allow proper flossing. If smoothing creates an open contact, solder can be added to the prosthesis.

When two proximal contacts are being restored, it

*Occlusal registration strips, The Artus Corporation, Englewood, NJ 07631.

FIGURE 17–3 Thin unwaxed floss used to test degree of proximal contact.

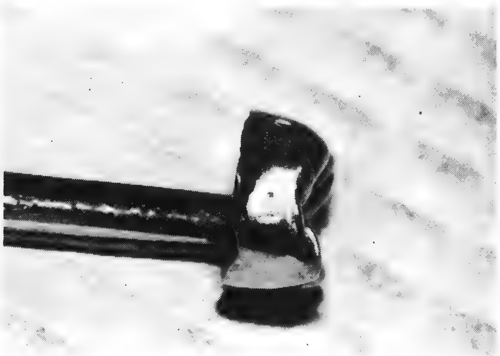


FIGURE 17–5 Proximal burnish mark produced from heavy proximal contact.

may be difficult to determine whether one or both contacts needs adjustment. Several observations can be useful in making the decision, but it sometimes must be based on trial and error. The resistance of each joint to the passage of floss is evaluated. Other contacts between unrestored teeth anterior and posterior to the prosthesis are tested with and without the restoration in place. Another method is to evaluate and compare the amount of marginal opening on the mesial and distal surfaces. When one proximal contact is heavier than another, the marginal opening usually is greater on the side of the heavier contact. Some patients may be able to identify whether they feel more pressure mesially or distally.

MARGINAL FIT

The marginal fit of a restoration is evaluated by using a sharp explorer. Wherever possible, the explorer tip is held perpendicular to the marginal area and moved occlusocervically across the margin (Fig. 17–6). The junction of the casting and the tooth is evaluated around the entire circumference of the tooth while finger pressure maintains complete seating of the casting. If the instrument tip enters between the restoration and the tooth, the casting is unacceptable. Sharp explorer tips average around 80 μm in diameter. Careful visual examination of accessible margins can reveal discrepancies that are not detectable with a sharp explorer.

Various factors other than heavy proximal contact can cause a fixed partial denture to exhibit unsatisfactory marginal adaptation. Some foreign material such as temporary cement between the restoration and the tooth can prevent complete seating. Other factors are related to either defective individual units or the need to reassemble properly fitting parts.

Determining whether the marginal discrepancy can be corrected by reassembly or is caused by unacceptable castings involves separating the prosthesis into individual parts by breaking a solder joint. With all-metal prostheses, the joint can be heated over a Bunsen burner flame and broken as described in the preceding chapter. With metal-ceramic components, the joint should be cut with a thin disc until it can be broken. Cutting of the joint avoids cracking of the porcelain in a flame.

Evaluation of the relationship of the pontic with the edentulous ridge tissue helps to determine whether one or more solder joints should be broken. When pontic alignment permits, it is advisable to break only one joint and to leave the pontic attached to one of the retainers. This facilitates reassembly. If the separated parts seat completely with no marginal discrepancy and proper pontic alignment, the prosthesis can be reassembled by obtaining an intraoral index of the positional relationship.

If one or more of the separated parts fails to have good marginal adaptation, that part must be remade. This condition can be the result of an inaccurate impression, damage to the prepared tooth margin after the impression was obtained, or faulty trimming of the die. Poor laboratory technique in waxing, investing, or casting can also lead to open margins or metal overhanging the finish line. Overtrimming of the die, overcarving of the wax pattern, or overpolishing of the casting produces a restoration that fails to cover all of the prepared tooth structure.

STABILITY AND RIDGE ADAPTATION

A restoration should not only seat completely but must be stable. There should be no rocking or springing of the prosthesis when forces are applied buccolingually, mesiodistally, or occlusocervically.

The pontic should be related to the edentulous ridge tissue according to the planned amount of contact. The absence of the desired contact or the presence of pressure on the tissue, as evidenced by blanching, is not acceptable. This condition could be caused by faulty pontic positioning during assembly or changes in the soft tissue brought about by a defective temporary restoration or poor oral hygiene procedures. Unless the condition is reversible, it is necessary to reshape or remake the pontic, depending on the type and magnitude of the defect.

FORM

The cervical contour of abutment retainers should be a continuation of natural tooth contour when this area

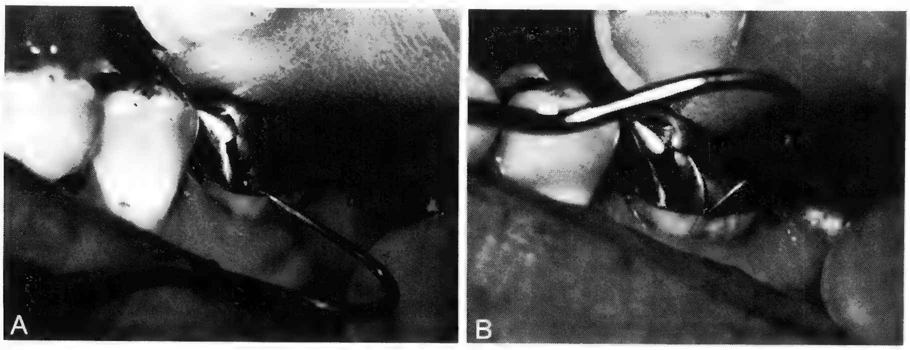


FIGURE 17–6
A, Evaluation of marginal fit with explorer held at right angle to margin.
B, Improper explorer angle for evaluating marginal fit.

is evaluated visually and when an explorer is moved back and forth between tooth structures and casting. Cervical overcontouring promotes plaque accumulation and is unacceptable. Small amounts of overcontouring can be corrected by recontouring the prosthesis, while generalized overcontouring necessitates that a new casting be made. Particular attention must be paid to cervical embrasure form and interproximal contour. Access to these surfaces with oral hygiene aids for plaque removal is mandatory. Also, the solder joint size, form, and location must permit access for cleansing the interdental margins.

OCCLUSAL ADJUSTMENT

Articulating ribbon or paper is placed between the restoration and opposing teeth so that contact marks occur when the mandible is closed (Fig. 17–7A, B). Areas of heavy contact are reduced by using abrasive stones (Fig. 17–7C), and adjustments are continued until there is simultaneous contact of restored and unrestored teeth. When attempts are made to pull thin occlusal registration strips* from between the occluded teeth, the same degree of resistance should be exhibited by all teeth (Fig. 17–7D). Rubber points† are used to polish roughened areas (Fig. 17–7E).

The teeth that are not being restored should contact in the same manner with and without the prosthesis present. There should be no sliding of opposing teeth on the castings. This condition is indicative of premature contact on the prosthesis, which causes the mandible to move to an eccentric position in order to achieve maximal closure. In addition, no contact of opposing posterior teeth should occur in nonworking or protrusive mandibular movements, since this condition may produce occlusal interferences with excessive forces on these teeth. Also, as a general rule, there should be no poste-

*Occlusal registration strips, The Artus Corporation, Englewood, NJ 07631.

†Brownie and Blue mini-points FG, Shofu Dental Corporation, Menlo Park, CA 94025.

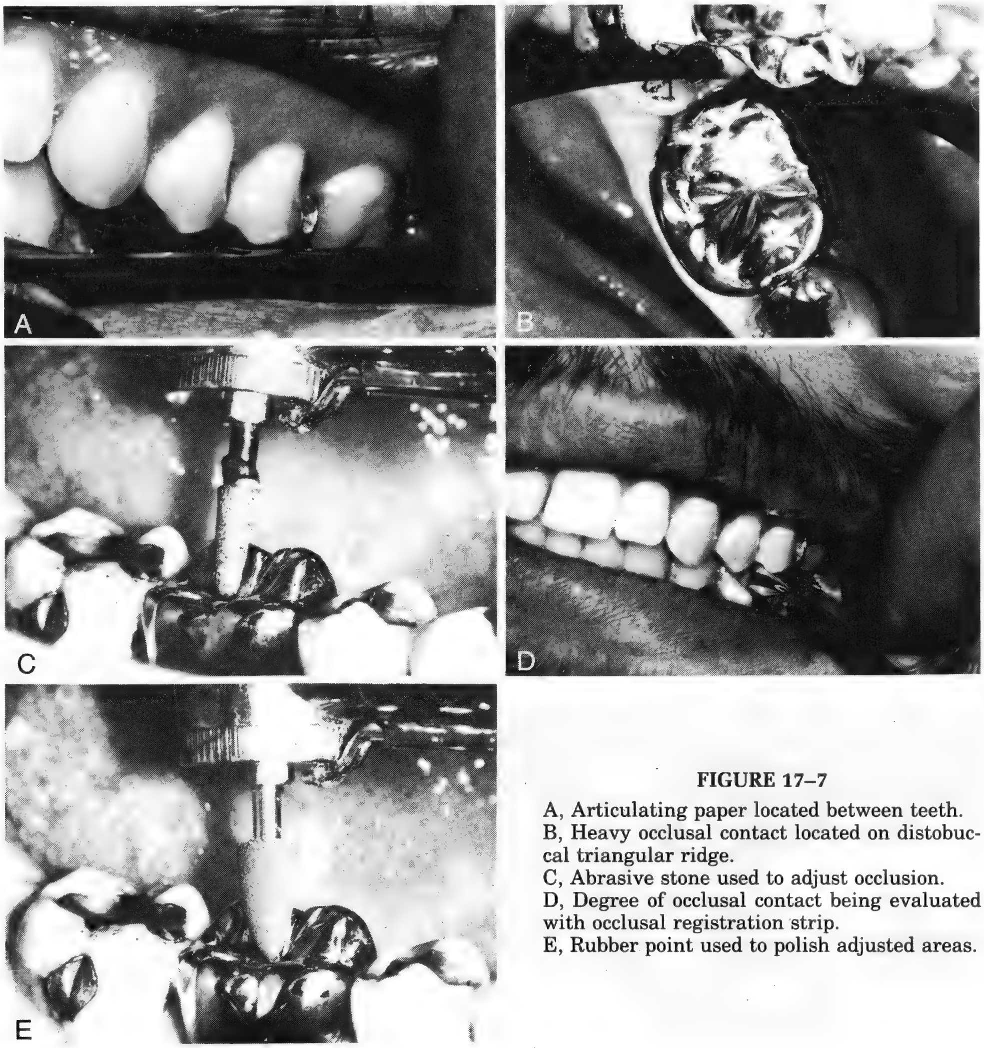


FIGURE 17–7

A, Articulating paper located between teeth.
B, Heavy occlusal contact located on distobuccal triangular ridge.
C, Abrasive stone used to adjust occlusion.
D, Degree of occlusal contact being evaluated with occlusal registration strip.
E, Rubber point used to polish adjusted areas.

rior tooth contact during working movements. However, exceptions exist owing to wear patterns on certain dentitions that require the use of a group function occlusion in which the canines and posterior teeth contact simultaneously during a working movement.

Occlusal contact marks from articulating ribbon or paper are often difficult to see when the metal is highly polished. For this reason, the final polishing of occluding surfaces with agents such as rouge should not be done until after occlusal adjustments are complete. Pressure-blasting of occlusal surfaces with fine-grit aluminum oxide to produce a mat surface can be used to facilitate evaluation of contact marks.

FINAL FINISHING AND POLISHING

Following occlusal refinement, the restoration is ready for final finishing. The marginal area should be refined and made as smooth as possible. This is done by holding the restoration in a fully seated position and using a fine-grit abrasive stone and small-diameter waterproof plastic discs* to smooth the interface from the tooth to the casting (Fig. 17–8). During finishing of the margin, instruments are slowly rotated so they turn from the casting to the tooth. The purpose of this procedure is to smooth and refine the margins of a well-fitting casting so there is less chance of plaque accumulation and to permit easier cleansing. It is *not* done in an attempt to correct a deficient marginal area. Attempting to close an open margin by dragging metal over the gap does not really solve the problem and only damages the tooth and the cervical contour of the prosthesis, and this cannot be done to any effective degree with the harder alloys required for fixed prosthodontics. The only acceptable cure for an open margin is the fabrication of a properly fitting casting.

The final polishing of the prosthesis with tripoli followed by rouge is done in the laboratory. The castings should be smooth and possess surfaces from which dental plaque can be easily removed.

VENTING AND RELATED PROCEDURES

It is known that the cement used to lute full-coverage restorations can impede or prevent complete seating of restorations. One of the factors is the thickness of the cement layer itself. This is traditionally referred to as the "film thickness." The term designates the thickness of the film of cement that remains after extrusion between two glass plates under a given load. The American Dental Association specification establishes a maximal film thickness of 25 μm, by that test, for a cement designed for cementation of a precisely fitting casting. If the film thickness is greater than this value, it may be difficult to completely seat a well-fitting casting.

Most types of dental cements have film thicknesses in the order of 18 to 22 μm, when handled properly, as described later in this chapter. However, several other methods have been developed to further improve the seating of the casting.

Venting of the casting by producing a perforation in the occlusal surface allows easier escape of the cement. Although venting is an effective method, it is not a widespread practice because of the time and expense involved in making a satisfactory repair of the vent hole

*Sand fine plastic disks (1/2-inch diameter), E. C. Moore Company, Dearborn, MI 48126.

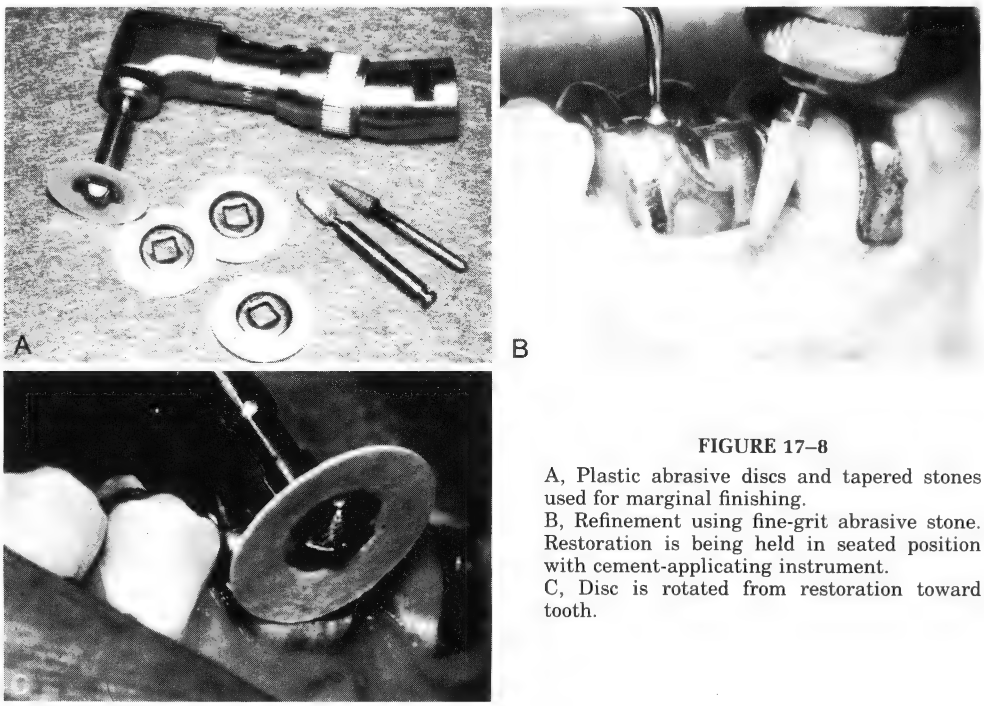


FIGURE 17–8

A, Plastic abrasive discs and tapered stones used for marginal finishing.
B, Refinement using fine-grit abrasive stone. Restoration is being held in seated position with cement-applicating instrument.
C, Disc is rotated from restoration toward tooth.

and the virtual impossibility of satisfactorily venting and repairing many metal-ceramic restorations.

Another method to permit more complete seating of a restoration is the use of a spacing medium—a varnish—on the die. The "die spacer" is applied to the occlusal or incisal surface and to the axial surfaces stopping short of the margin. The applied film produces a space between the casting and the axial walls of the preparation, except at the margin. Theoretically, the additional space allows the cement to escape more readily and reduces the effect of the film of cement on the degree to which the casting will seat. This approach is thought by some authorities to improve the marginal adaptation of cemented restorations, and it is in widespread use.

Another approach to expediting the escape of cement is the production of a vertical groove in the tooth, which runs from the occlusal surface to a point near the cervical margin. Obviously, the groove should be placed after the impression has been obtained and the casting made. This method has been shown to be effective, at least in laboratory tests.

In spite of the foregoing information, many dentists find that satisfactory clinical results may be obtained without resort to venting or related procedures.

A number of factors tend to compensate for the cement film. For example, studies in this area have usually involved castings made directly on the test specimen. Since all die stones have some setting expansion, the resulting die is somewhat larger than the tooth preparation. Certain impression materials produce a slightly larger reproduction of the tooth, which creates a slightly looser fit of the casting. In addition, the investing and casting process often yields minutely oversized castings.

Also, certain laboratory procedures advantageously affect the available cement space, without adversely influencing marginal adaptation. For example, the use of separate dies and casts obtained from the same elastomeric impression may result in a slightly larger reproduction of the prepared tooth on the cast than is represented by the die. Transferring the pattern from die to cast and back to die would thus slightly enlarge the pattern. The use of more than one die might further accentuate the difference. Finalizing the marginal adaptation on the die would ensure an accurate marginal fit without complete internal readaptation of the pattern.

The individual operator should weigh carefully the advantages and disadvantages offered by these various methods intended to improve seating on cementation against any problems that have been encountered in this regard.

DENTAL CEMENTS

Classification of Dental Cements

Dental cements are generally classified according to composition. With the exception of the calcium hydroxide and resin materials, the setting reactions are those typical of an acid and a base. The liquids act as the acid, and the powders as the base.

The American Dental Association specifications for the various cements further classify certain of the ce-

FIGURE 17–9 Commercial products representative of the various types of cements used for luting purposes. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 454.)

ments as Type I and Type II on the basis of their properties and thus their intended use. For example, a Type I *zinc phosphate* cement has a fine-grain small-particle size intended for cementation of precision-fitting castings. When used in this manner, such cements are usually referred to as *luting* agents. The Type II zinc phosphate cement is a medium-grain cement and is recommended for all other uses, such as thermal insulating bases and cementation of orthodontic bands. Representative products of the various types of luting cements are shown in Figure 17–9.

Zinc Phosphate Cement

Since zinc phosphate is the oldest of the luting cements and thus is the one that has the longest track record, it serves as a standard with which newer systems can be compared. Furthermore, much of the basic information discussed in the following sections is directly applicable to other types of cement.

The powder is principally zinc oxide, and the liquid is essentially phosphoric acid and water. Metallic salts (known as *buffering salts*) are added in order to reduce the speed with which the liquid and powder react, thus aiding in securing a smooth uniform mix, as well as providing sufficient setting time.

The average water content in the liquid is approximately 33 per cent. This is a critical ingredient because it partially controls the rate at which the liquid and powder react.

Although the composition of the liquids for various brands of cements is similar, generally the liquid from one manufacturer cannot be used with the powder from another manufacturer. The composition of the liquid is critical and is balanced to that of the powder. When a zinc oxide powder is mixed with phosphoric acid, solid zinc phosphate is rapidly formed, accompanied by considerable evolution of heat.

The hardening process continues after the mixture is placed in the mouth, as the zinc phosphate continues to form. The final hardened cement is made up of the original undissolved powder particles suspended in a matrix composed of the new zinc phosphate compound. As is true for virtually all cements, the weakest and most soluble component of the cement is the matrix.

Properties

The hardening or setting time of the cement must be accurately controlled. The cement should set slowly enough to allow sufficient working time for proper insertion of the restoration. On the other hand, if the setting time is prolonged, the time required for completing the operation is unduly long.

Setting time is particularly critical when more than one unit is being cemented. If the cement hardens too rapidly, the restoration or prosthesis does not go completely into place. If too much time elapses between mixing and use, the setting reaction progresses to the degree that the cement becomes too viscous to squeeze out into a film that is thin enough to permit the casting to fully seat on the prepared tooth. In other words, the thickness of the film formed by the cement is greater than the space between the cast restoration and the tooth. Once the proper consistency is obtained, the "race" begins between the advancing chemical reaction that is thickening the cement and the insertion of the restoration into the mouth.

The setting time is influenced by the manufacturing process as well as the method of manipulation. The composition and particle size of the powder are important factors. As already described, the composition of the liquid is also critical, owing to the presence of the buffering salts and water.

In a sense, when the powder and liquid are mixed, the manufacturing process is continued by the person who mixes the cement. A number of manipulative factors influence the setting time. Setting time is controlled by regulating the temperature of the mixing slab. If the mixing slab is cooled, the chemical reaction proceeds at a slower rate so that the products that cause the cement to set form more slowly.

There is another important reason for slowing the setting reaction by use of a cool slab. This method permits a maximal amount of powder to be incorporated into the liquid without undue increase in the viscosity of the mix. For maximal physical properties, a high powder-liquid ratio is desirable.

Usually it is recommended that the slab not be cooled below the dew point, that is, the temperature at which moisture from the air starts to condense. In such a case, moisture would form on the slab and be incorporated into the mixture. Moisture may affect the setting time and also impairs the properties of the cement.

The rate at which the powder is added to the liquid also provides a means of controlling the setting time. Adding the powder in small amounts, with thorough mixing of each increment, can extend the setting time.

As already discussed, the water content of the liquid is carefully established by the manufacturer and must be maintained. If the cap is left off the bottle of liquid or if the liquid is placed on the mixing slab for any period of time, the water may evaporate or the liquid may gain water if the relative humidity in the office is high. In either case, the setting time and properties of the cement are impaired. Thus, it follows that the cap should not be left off the bottle of liquid any longer than necessary and that the powder and liquid components should not be dispensed until just before the mix is to be made.

Ideally, adhesion between the cement and tooth structure would be most desirable. However, with the exception of the polycarboxylate and glass ionomer cements, none of the luting agents truly adheres to enamel or dentin. Any adhesion secured is merely a mechanical interlocking between the cement and the materials being joined by the cement.

For example, when a crown is cemented, the surfaces of the metallic restoration and the tooth structure are somewhat rough and serrated. The cement is forced into the irregularities. After the cement has hardened, the resistance of shear stresses by these extensions of cement assist somewhat in retention of the restoration. This mechanism is illustrated in Figure 17–10. However, it should be emphasized that the crown is held in place principally by the retention provided in the design of the cavity preparation.

The thickness of the film between the crown and the tooth is also a factor in retention. As mentioned previously, this particular characteristic of the cement is referred to as the *film thickness*. The thinner the film,

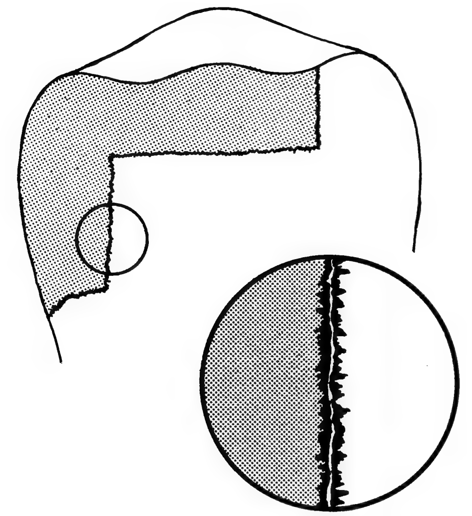


FIGURE 17–10 A diagram of the suggested mechanism whereby a dental cement provides mechanical retention of a gold inlay. The cement penetrates into irregularities in the tooth structure and the casting and upon hardening aids in holding the restoration in place. The enlargement shows fracture of these tiny cement projections and loss of retention, possibly resulting in dislodgment of inlay. (From Phillips, RW, Swartz, ML, and Norman, RD: Materials for the Practicing Dentist, St. Louis, C.V. Mosby Company, 1969; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 463.)

the better is the retention. A consistency of low viscosity permits the cement to flow into the minute surface irregularities and to wet the surface. If the cement film is thin, the layer of cement between the casting and the prepared cavity does not interfere with the fit of the restoration. A thinner cement film generally improves retention.

The thickness of the cement film also is governed by manipulative factors such as the powder-liquid ratio, the temperature, and the pressure used during cementation of the casting. The American Dental Association specification states that the Type I cement that is fine-grained must have a film thickness no greater than 25 μm, as was noted earlier.

Of course properties other than film thickness influence the cement bond. For example, the strength of the cement will affect the ease with which these small extensions, or locks, are fractured under biting stresses. If they break, mechanical retention from the cement is lost, as illustrated in the enlargement in Figure 17–10. It must again be emphasized that such a mechanism must not be relied upon as the primary means of holding the restoration in place. Retention is obtained primarily by the design of the preparation and the accuracy of fit of the casting.

The strength of dental cements is usually determined under compression. The American Dental Association specification no. 8 requires a minimal compressive strength of 700 kg per sq cm (9960 psi) at the end of 24 hours. Although the cement film is more likely subjected to a shear type of stress than to a compressive stress when the restoration is placed under masticatory forces, the compressive strength of the cement is apparently indicative of its mechanical retentive characteristics. In other words, the greater the compressive strength of the cement, the less likely it is that the restoration will be dislodged.

As previously stated, the strength of the cement primarily depends on the powder-liquid ratio. The compressive strength increases rapidly as the amount of powder is increased.

Probably, the property of greatest clinical significance is the solubility and disintegration of the cement, which is a characteristic that is most important in the use and selection of any dental material. When the dentist places the crown over the prepared tooth, excess cement is forced out between the restoration and the tooth. However, regardless of the seating force used, there is always cement between the casting and the tooth although this *cement line* may not be visible to the naked eye. This exposed cement can gradually dissolve, permitting microorganisms and debris to penetrate between the tooth structure and the crown. In that event, the restoration may become loose and caries may develop.

From the standpoint of the material itself, cement solubility is probably a significant factor contributing to secondary caries around the crown or fixed bridge. Every precaution must be taken to produce a restoration that fits accurately so that the layer of exposed cement is minimal. In addition, the cement should be handled in such a manner that the solubility is as low as possible.

The greater the amount of powder incorporated into the liquid, the greater is the number of core particles and the less the amount of matrix. Because the particles of the original powder are considerably less soluble than the matrix material, the disintegration is less. Thus, the use of a cool slab is essential in order to provide ample time for incorporating the maximal amount of powder within the limits required to maintain the proper consistency for the intended task.

The cement is particularly vulnerable to attack by oral fluids during the first 24 hours. For this reason, it is recommended that the exposed margins of newly cemented restorations be protected by a coat of cavity varnish during this critical time.

Zinc phosphate cements contain phosphoric acid, and thus the pH is quite low at the time they are placed in the tooth. Although the pH does rise as the setting reaction progresses, these cements are quite irritating to the dental pulp. Thus, in a deep-cavity pulp, protective measures are required, as discussed later.

Manipulation

The important manipulative variables that control the rate of the reaction between the powder and the liquid and the behavior and properties of the cement have been discussed. The following points summarize the factors to be observed in preparation of the cement mix.

Although desirable, a measuring device is not ordinarily employed for proportioning the powder and liquid, because the consistency varies for the purpose intended. A somewhat thinner consistency is required when the cement is to be used as a luting agent as compared with that desired when it is to serve as a base. Experience gained in manipulating cement and the handling characteristics desired by the dentist are the best guides to attaining mixes of the proper consistency. However, the maximal amount of powder possible for the intended

FIGURE 17–11 Slab and spatula used for mixing zinc phosphate cement. The initial portion is being incorporated into the liquid. Note that the caps are replaced on the bottles to protect the powder and liquid. (From Phillips, RW: Elements of Dental Materials for Dental Hygienists and Assistants. 4th ed. Philadelphia, W. B. Saunders Company, 1984, p. 312.)

use should be incorporated in order to reduce the solubility and to increase the strength of the cement.

A cool mixing slab should be employed. The slab may be cooled in a refrigerator or under cold running water. However, the surface of the slab should be thoroughly dried.

The mixing is started by the addition of small amounts of powder, as illustrated in Figure 17–11. Small quantities of powder are then incorporated bit by bit, using a brisk rotary motion of the spatula (Fig. 17–12). A considerable portion of the mixing slab is used. A good rule is to spatulate for approximately 20 seconds before adding the next increment. The total mixing time is not unduly critical, but the mix usually requires approximately 1.5 minutes to be completed. Although a stopwatch is shown in Figure 17–12 for use in timing the spatulation of each increment, it is not generally needed once experience has been gained in identifying the proper appearance of the mix as it progresses. The desired consistency is always attained by the addition of more powder and *never* by allowing a thin mix to stiffen. More liquid is never added to thin a mix that is too stiff; the mix is discarded and another mix is made.

Zinc Silicophosphate Cement

This cement is a combination of the silicate and zinc phosphate cements. The powder contains both silicate and zinc oxide. Just as with zinc phosphate, the main components of the liquid are phosphoric acid and water. Type I zinc silicophosphate cements form sufficiently thin films to permit cementation of precision castings. The cement is somewhat translucent, and thus esthetically it is particularly appropriate for cementing all-porcelain restorations.

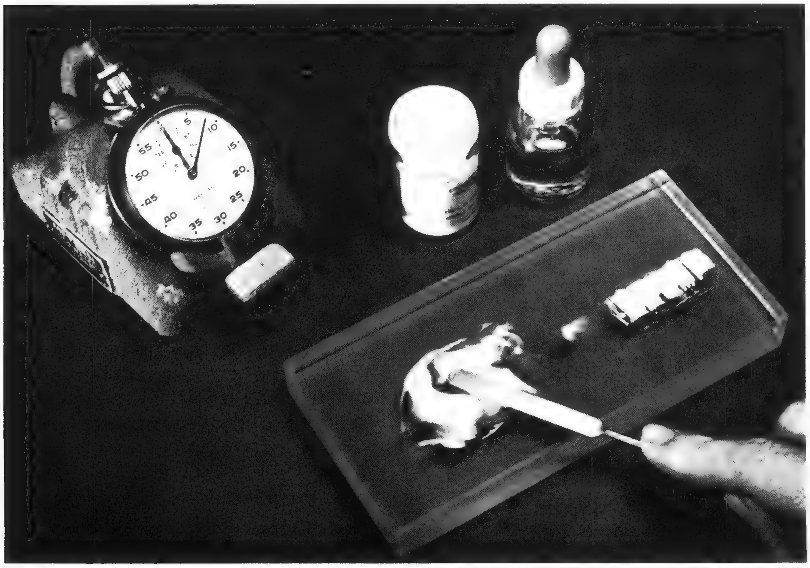


FIGURE 17–12 In mixing zinc phosphate cement, a rotary motion is used and a large portion of the slab is utilized. (From Phillips, RW: Elements of Dental Materials for Dental Hygienists and Assistants. 4th ed. Philadelphia, W. B. Saunders Company, 1984, p. 323.)

As would be expected, the properties of these cements tend to fall between those of zinc phosphate cements and silicate cements. Because of the phosphoric acid, they can irritate the pulp, and proper protection is required. They do possess anticariogenic properties by virtue of the fact that the powders contain fluoride.

The cement is mixed on a cool dry slab, as described for zinc phosphate. However, the powder usually is incorporated in two or three large increments, with a total mixing time of approximately 1 minute.

Improved Zinc Oxide-Eugenol Cement

The biologic properties that have made zinc oxide-eugenol so useful for temporary restorations and for cementation of temporary restorations also make it attractive as a permanent cement. However, the low strength of traditional zinc oxide-eugenol mixtures has limited its potential for that usage. In order to improve the compressive strength of the cement, various additives have been used, such as polymers and inorganic compounds. Another common additive is *o*-ethoxybenzoic acid (usually referred to as EBA), which is placed in the eugenol.

These formulations have been referred to as "fortified," "reinforced," "modified," or "improved" zinc oxide-eugenol cements. Commercially, some are called EBA cements when the product contains *o*-ethoxybenzoic acid. The physical properties, such as strength, are superior to those of the conventional or unreinforced zinc oxide-eugenol cements but inferior to that of zinc phosphate cement.

The properties of these cements generally are less sensitive to manipulative variables as compared with those of zinc phosphate cement. Higher powder-liquid ratios result in somewhat greater strength, but the rate at which the powder is incorporated into the liquid is not critical. Lowering the slab temperature, as long as it is not below the dew point, slows the set of the cement somewhat.

Because of their excellent biologic properties, these cements achieved a considerable degree of popularity. However, they present some problems in manipulation and long-term durability in the oral cavity. For these reasons, some of the newer cements that are equally biologically "kind," such as zinc polycarboxylate, have largely replaced these zinc oxide-eugenol cements for permanent cementation.

Zinc Polycarboxylate Cement

Cements of this type are referred to as *polycarboxylate* or *polyacrylate* cements. They are particularly noteworthy, since this was the first system developed that demonstrated a potential for chemical adhesion to tooth structure. The powder of this cement is similar to that of zinc phosphate cement. It contains zinc oxide and originally contained a small amount of magnesium oxide. Some products now substitute stannic oxide, as well as stannous fluoride, for the magnesium oxide in order to modify setting time and to improve the strength and handling characteristics. (Perhaps it should be mentioned that in this case the added fluoride seems to afford little potential for anticariogenic protection.) The liquid is polyacrylic acid and water.

When the zinc oxide powder is mixed with the polyacrylic acid, the cement-forming mechanism is thought to be a reaction of zinc ions with the polyacrylic acid via the carboxyl groups. The chemical reaction by which the adhesive bonding of the cement to the tooth structure is achieved appears to be similar to that of the setting reaction.

The polyacrylic acid reacts with the calcium of the hard tooth structure (the inorganic portion) in much the same manner as it reacts with the zinc of the zinc oxide powder, as is illustrated in Figure 17–13. The bond of the cement to enamel is stronger than that to dentin. This finding is not surprising, since enamel contains a much higher percentage of calcified material than does dentin. There is some evidence that the cement also may bond to the organic collagen of the dentin, but such bonds are much weaker.

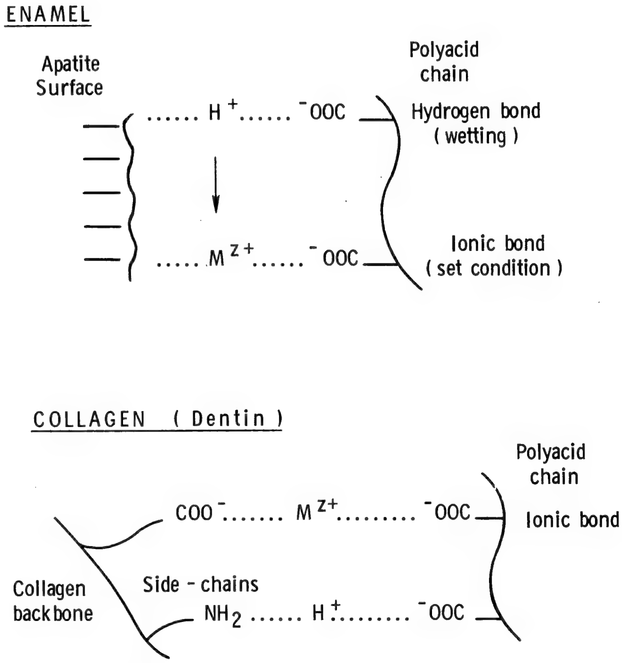


FIGURE 17–13 The diagram illustrates postulated mechanisms for the adhesion of polycarboxylate and glass-ionomer cement to enamel and dentin, as suggested by Wilson, AD, in *Aspects of Adhesion-8, Transcription Books,* 1975, pp. 285–306. The upper diagram shows a suggested mechanism whereby the fresh mobile cement paste wets and adheres to the enamel apatite surface by hydrogen bonds provided by free carboxylic acid groups. As the cement reaction proceeds, most of these hydrogen bonds, as represented by the arrow, are replaced by metal ions to give metal bridges that provide adhesion for the cement to the enamel.

The lower diagram illustrates possible mechanisms of adhesion between those cements and dentin. Collagen contains some branch chains that terminate in carboxylic acid groups and others that terminate in amino groups. The former can link to the cement mass by metal ion bridging, while the latter groups bond by hydrogen bridges. (By permission of A. D. Wilson, Laboratory of the Government Chemist, Crown Copyright; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 472.)

Some polycarboxylate cements are marketed as a powder only, which is mixed with water. In these products, freeze-dried polyacrylic acid is mixed with the cement powder. When this powder is mixed with water, the dried acid powder dissolves and the setting reaction proceeds just as with the powder-liquid systems.

Properties

Although the tensile strengths of polycarboxylate and zinc phosphate cements are similar, the compressive strength of a cementing consistency of polycarboxylate cement is less than that of zinc phosphate cement. However, the strength of these cements is affected somewhat less by small variations in powder-liquid ratio than is the strength of zinc phosphate cement.

The solubility of polycarboxylate cement in distilled water is similar to that of zinc phosphate cement, and its solubility increases when it is exposed to organic acids, just as for other cements. When the cement is mixed properly, the mixture appears quite viscous. Despite the appearance, if handled correctly, the film thickness will be 25 μm or less.

The pulp reaction to polycarboxylate is mild, being comparable with that produced by zinc oxide-eugenol. It is possible that the large size of the polyacrylic acid molecule and its tendency to form complexes with the tooth, and thus to retard penetration through the dentin, explain its biocompatibility with the pulp.

In addition to the biologic qualities of the cement, another cited advantage is the potential of the cement to truly adhere to tooth structure. Nevertheless, this characteristic may not be so significant in increasing the retention of a metallic restoration, since the bond to the alloy is not greatly superior to that of other types of cements.

Manipulation

The polycarboxylate cement is often handled improperly, and the success of the restoration suffers accordingly. Too frequently the dentist or auxiliary who has had experience in mixing zinc phosphate cement uses the same technique with a polycarboxylate cement. Several steps in manipulation are quite different. Factors to be watched are as follows:

The recommended powder-liquid ratio is approximately 1.5 gram of powder to 1 gram of liquid. A porportioner for the powder is usually furnished. One product also has a calibrated syringe available for the liquid. It should be cautioned that polycarboxylate liquid (or any polyacrylic acid-containing cement liquid) should not be stored in a refrigerator. The low temperature causes the liquid to thicken or gel.

The cement may be mixed either on a glass slab or a nonabsorbing paper pad. The glass slab is somewhat advantageous, since it can be cooled. Just as with zinc phosphate cement, this slows the chemical reaction and thereby provides a little longer working time, which is usually quite short. The powder is dispensed onto the slab first. The liquid should never be dispensed until just before the mix is to be started, as for other cements. Exposure of the liquid to the air for only a few minutes results in evaporation of the water, which produces an increase in the concentration of the polyacrylic acid and hence the viscosity of the liquid.

All of the powder is incorporated into the liquid in two or three large increments, using rapid spatulation. The mix should be completed in 30 seconds so that the dentist has sufficient time to apply the cement and seat the restoration before the viscosity becomes too high. A proper mixture of polycarboxylate cement is somewhat thick in appearance but has a shiny glossy surface. It forms a thin strand when it is picked up by the spatula, as is shown in Figure 17–14A.

When the mixing time is prolonged, the cement takes on a dull appearance and becomes tacky, as seen in Figure 17–14B. It should be remembered that the wetting of the tooth structure, as well as the bond to it, is based on a reaction with the polyacrylic acid liquid. Therefore, everything in the technique hinges on having some liquid still available in the mix when it comes in contact with the tooth. Also, the tooth surface must be meticulously clean, as previously described, in order to achieve a good bond with the cement.

Failure of the cemented gold restoration can often be traced to a loss of retention at the casting-cement interface. The bond of this type of cement to the "as cast," or "pickled," gold-based restoration is poor owing to the chemically dirty metal surface left from the acid pickling solution. Therefore, before cementation the inside surface of the casting should be cleaned with an airborne abrasive or carefully abraded by use of a rotary dental abrasive tool (as described later) and then thoroughly rinsed and dried. Only then does this type of cement adhere to the metal.

Glass Ionomer Cement

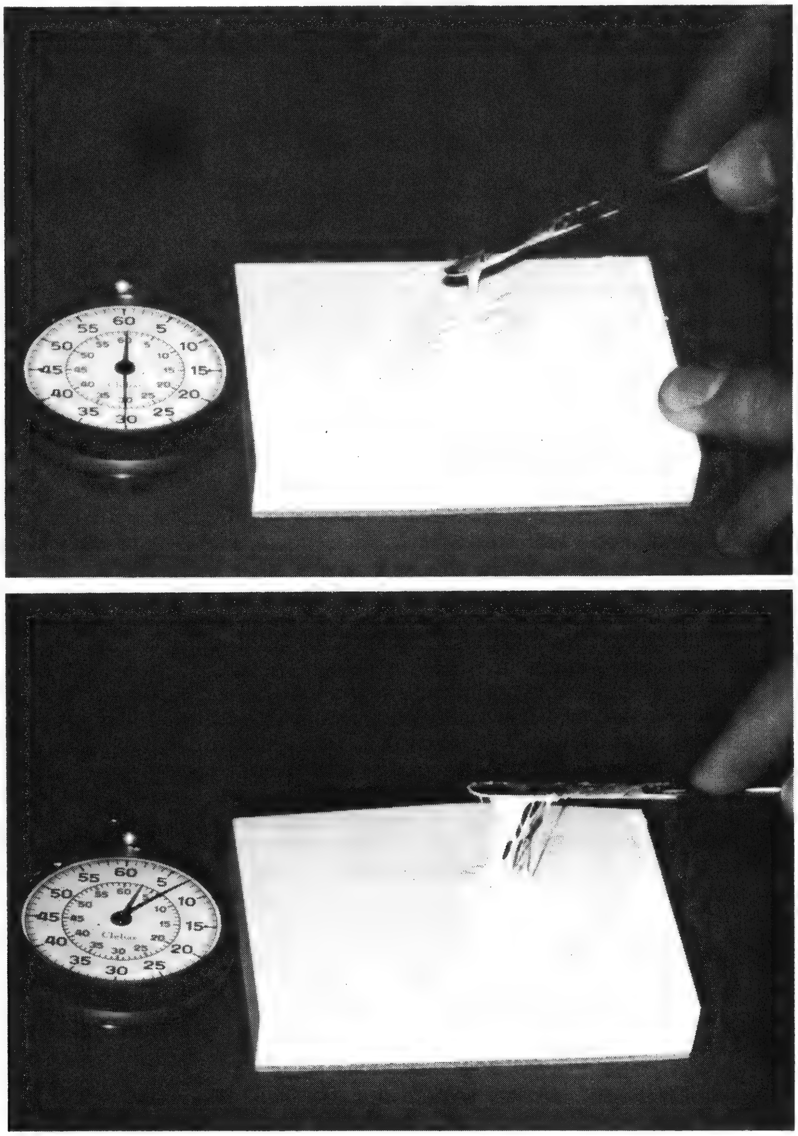
This is the newest of the dental cements. The powder is an aluminosilicate glass similar to silicate cement powder, and the liquid is basically polyacrylic acid along with some other organic acids and water. It is similar in composition to polycarboxylate cement liquids but generally somewhat less viscous. These cements, just as with the polycarboxylate cement, can be prepared with the freeze-dried polyacrylic acid incorporated in the powder.

Properties

The compressive strengths of glass ionomer luting cements usually are in the range of the zinc phosphate cement's. The 24-hour solubility in distilled water is higher than that of zinc phosphate cement and even that of zinc silicophosphate cement. However, solubility tests conducted in the oral cavity suggest that both glass ionomer and silicophosphate cements are actually more resistant to deterioration in oral fluids than is either zinc phosphate or polycarboxylate cement.

The glass ionomer cements adhere to tooth structure just as do polycarboxylate cements. The adhesion is by virtue of the polyacrylic acid in the liquid, the mechanism being the same as that discussed for the polycarboxylate cements.

The glass ionomer cement is considered to be relatively kind to the pulp, although in the case of near-pulp exposures, pulp protective measures are probably well advised. Surprisingly, considering the accepted biocompatible nature of polyacrylic acid–based cements, some instances of postoperative sensitivity have been



A

B

FIGURE 17–14

A, Consistency of mix of polycarboxylate cement on completion of 30-second mix.
B, If mixing time is prolonged or the mix is allowed to remain on the slab, the cement becomes dull in appearance and the consistency tacky.
(Courtesy of M. Jendresen; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 476.)

reported. It is true that the pH of this cement, coupled with its relatively slow set, could be a potential source for pulpal irritation in isolated cases. For example, a very deep preparation involving possible pulpitis could be a contributing factor, particularly when the casting fits very tightly and the hydraulic pressure during seating could enhance penetration of the acid into the tubules. This again emphasizes the importance of placing a small dab of calcium hydroxide base over these suspicious areas. Likewise, proper technique in using the cement, as is described, will minimize the possibility of microleakage, which could also contribute to the pulpal irritation.

Also, this cement possesses, just as does zinc silicophosphate, the potential for inhibiting or reducing secondary caries. This potential is related to the slow release of fluoride that is an ingredient in the silicate glass powder.

Manipulation

Most of the rules for manipulation of polycarboxylate cement apply also to the glass ionomer cements. The prepared tooth structure must be meticulously cleaned and dried in order to attain adhesion of the cement to the tooth. Likewise, the inside surface of the casting must be cleaned, as was noted for the polycarboxylate cements.

The recommended powder-liquid ratio varies with different brands, but it is in the range of 1.25 to 1.5 grams of powder per gram of liquid. As with all cements, reduced powder-liquid ratios impair properties. Thus, the manufacturer's directions relative to proportioning should be followed. The cement can be mixed on a nonabsorbant pad or a cooled glass slab. Use of the cool slab is advantageous, since glass ionomer cement, like polycarboxylate cement, has a short working time, and

the reduced temperature slows the setting reaction somewhat. The powder is incorporated into the liquid in two or three large increments with rapid spatulation. The total mixing time should be 45 seconds.

Cementation should be done before the cement loses its shiny appearance in order to obtain adhesion to the tooth.

The glass ionomer cement is particularly susceptible to attack by water during its setting. Therefore, it is necessary to coat all of the accessible margins of the restoration with a varnish, as supplied by the manufacturer, to protect the cement from premature exposure to moisture.

Resin Cement

Currently there are two types of resin cements on the market for cementation of castings. Basically the compositions are that of chemically activated direct-filling resins, poly(methyl methacrylate), and BIS-GMA. Both contain fine-particle fillers to reduce the coefficient of thermal expansion and polymerization shrinkage.

From the standpoint of properties, the principal advantage of these cements is that they are virtually insoluble in water. In other respects, they are inferior to other cementing media. They are somewhat irritating to the pulp. Thus, it is essential that the pulpal wall be protected by a layer of a calcium hydroxide cement. Like other resins, they do not adhere to tooth structure. Thus, in time water may penetrate the tooth-cement interface.

The manipulative characteristics are somewhat inferior to those of most other types of cements. With some resin cements, the film thickness is often high, and difficulty has been encountered in obtaining complete seating of the casting. Also, the time at which the excess cement (flash) is removed is critical. The flash should be removed immediately upon seating of the casting. If done while the cement is in a rubbery stage, some of the cement may be pulled out from under the casting. The resulting void at the margins then increases the susceptibility to secondary caries. Removal of the flash is difficult if it is delayed until polymerization of the cement is completed. For such reasons, the resin cements have not been widely used for cementation of precision castings.

Selection of a Cement

It is obvious that a wide variety of cements are available for use as luting agents for cast restorations. Each type has certain individual beneficial characteristics, yet none meets all the requirements of the ideal cement, that is, insolubility, adhesion to tooth structure, sufficient strength, and biologic compatibility. Although the dentist may prefer to use one type of cement for cementation of the majority of restorations, in certain instances there may be a need to alter the type of luting agent because of the particular circumstances involved.

For example, the oldest type of cement, zinc phosphate, is still very popular. It can be manipulated easily, the exact relationship between properties and clinical performance has been established, and it has a long history of successful use. These factors account for its continuing popularity in spite of its irritating effects on the pulp if proper protection is not provided.

However, through experience the dentist recognizes certain situations in which the biologic characteristics of the cement are the most important considerations, such as when caries or previous history indicate that the condition of the pulp will probably lead to postoperative sensitivity. In this case a cement that is more biocompatible than zinc phosphate is indicated, such as a polycarboxylate, glass ionomer, or improved zinc oxide-eugenol.

Other situations encountered involve patients whose mouths have a high caries index and patients who do not practice good oral hygiene. Here a prime consideration is the capability of the cement to provide maximal resistance to caries at the marginal areas of the restoration. The luting agent preferred is a glass ionomer or a silicophosphate cement.

Only through experience and an appreciation of the inherent biologic and physical properties of each type of cement can the correct type be selected to cope with the diverse conditions that are met within a dental practice.

GENERAL CEMENTATION PROCEDURES

As previously stated, both the casting and the prepared tooth surfaces must be clean and free of foreign materials. The castings should be ultrasonically cleaned to remove any residual polishing compounds and then dried with compressed air so the metal surface can be visually inspected for cleanliness.

In the case of the polyacrylic acid-based cements, it is particularly important to have a microscopically clean surface on the casting. One of the problems is the manner in which the casting is fabricated. As noted earlier in Chapter 15, after the casting is removed from the investment it is placed in a warm bath of an acid or a salt of an acid to remove oxides and any adhering film of investment. Although the surface appears shiny and clean, even if it has been washed or scrubbed, actually it is covered by a thin film of a sulfide or chloride left by the acid.

Polyacrylic acid, which is present in the polycarboxylate or glass ionomer cements, is repelled by this dirty surface, which prevents bonding of the cement to the metal. Microleakage may then occur at the cement-casting interface and results in loss of retention. This chemically dirty surface must be mechanically cleaned by careful use of a fine stone. A number of companies supply an "air eraser,"* which provides a small stream of a fine aluminum oxide powder for such a purpose. Regardless of the method used, it is essential that the surface of the casting be mechanically cleaned when this type of cement is employed.

Cotton rolls are placed in the facial vestibule, and also lingually when mandibular teeth are involved, in order to absorb saliva and maintain moisture control (Fig. 17–15). The presence of heavy salivation often requires that cotton rolls be changed several times during the cementation procedure. Compressed air is used to dry the prepared teeth so the cement is not adversely affected by a wet contaminated environment

*Paasche Airbrush Company, Chicago, IL 60614.

FIGURE 17–15 Cotton rolls placed in the facial and lingual vestibules to help absorb saliva during cementation.

FIGURE 17–16 Thin layer of cavity varnish being applied to prepared tooth with cotton pellet.

during setting. The dry teeth also permit a final visual evaluation of cleanliness. If a subgingival finish line is present and there is bleeding, the use of a hemostatic agent and retraction cord helps to maintain a clean dry working area. On occasion it may also be necessary to have the patient take an antisialagogue to help control excessive salivation during cementation.

When cements are used that contain an acid known to be irritating to the dental pulp, such as zinc phosphate, it is recommended that cavity varnish be placed on the prepared surfaces (Fig. 17–16). This is particularly important over deeper portions of the preparation that are closer to the pulp. The varnish should be applied in two or three *thin* coats to the incisal or occlusal portion of the preparation but must not be placed over the finish line or shallower cervical area of the preparation. When properly applied, varnishes can help prevent acid irritation of the pulp without interfering with the retention of the restoration on the prepared tooth. Any varnish with a thick consistency should be thinned using the proper solvent or discarded, since thick layers of varnish reduce casting retention.

A thin layer of the properly mixed cement is applied to the internal aspect of the casting. The use of a small instrument for cement placement helps prevent entrapment of air between the cement and the restoration. Filling of the entire internal aspect of the casting with cement is not necessary with a properly adapted restoration. This only makes seating of the prosthesis and cleanup procedures more difficult.

Successful cementation of castings with pins or other intracoronal retentive features requires that cement be placed into the prepared recesses of the tooth prior to seating of the restoration. This process prevents air from being trapped as the restoration is seated and assures optimal retention by allowing the cement to achieve good contact with both the prepared tooth and the restoration. A slowly rotating spiral instrument* is very effective for placing cement into these intracoronal areas.

SEATING THE RESTORATION

When the cement is properly mixed, forceful finger pressure adequately seats most restorations. As the casting is seated, a faciolingual tipping motion facilitates expressing the excess cement (Fig. 17–17). When a lower restoration is being seated, the mandible should be supported from the underside during the application of force. The headrest of the dental chair generally provides adequate support for the cementation of a

*Lentulo Spiral Instrument, Star Dental Manufacturing Company, Philadelphia, PA 19482.

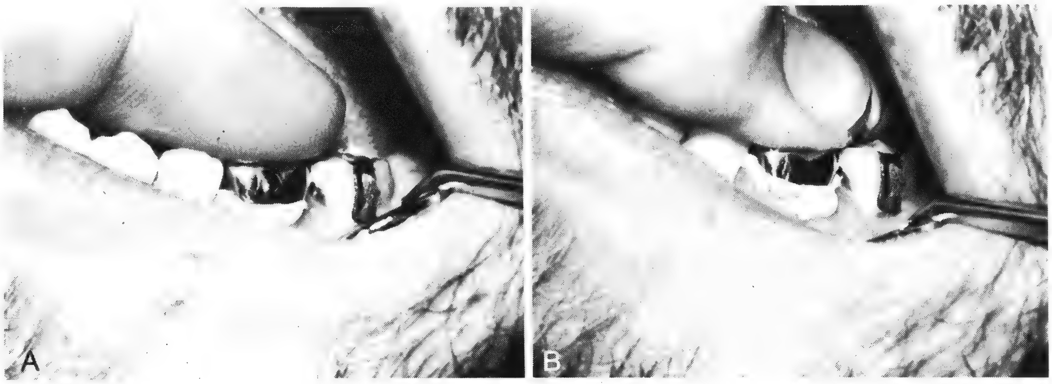


FIGURE 17–17

A, Casting seating with force applied to lingual cusps.
B, Force transferred to the facial cusps.

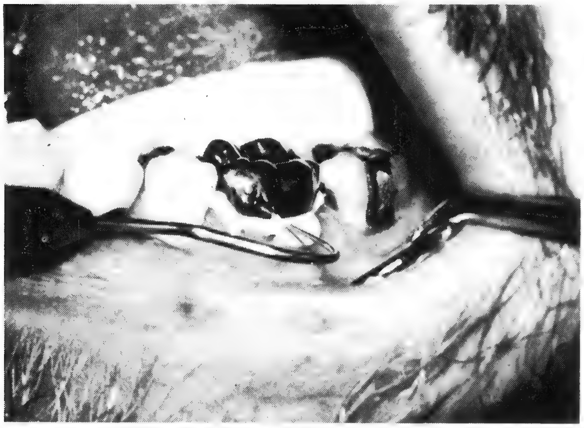


FIGURE 17–18 Marginal fit checked through the cement to determine whether complete seating has been achieved.

maxillary restoration. Forceful blows of short duration, as from a mallet and wooden stick, are not effective in expressing viscous hydraulic fluids such as dental cements. Malleting can also damage the restoration or tooth and is certainly not comfortable to the patient.

When a restoration appears to be completely seated from forceful finger pressure, the casting margins should be checked with the same explorer as is used prior to cementation (Fig. 17–18). This helps to determine whether complete seating has occurred. When supragingival margins are present, a small cotton pellet can be used to clean the excess cement from a small area of the margin. More force can then be applied to see whether additional cement can be expressed (Fig. 17–19). The application of force is continued until no additional cement is expressed and the restoration is fully seated.

The patient's muscles of mastication can also be used to promote complete seating of the restoration. Biting forcefully and continuously on a wooden stick can be helpful (Fig. 17–20A), but care must be taken to prevent the stick from contacting only one cusp or an area of the casting that could produce tipping instead of complete seating. Wooden pegs* are available (Fig. 17–20B, C) that can be placed and held in the center of the casting by the opposing dentition to reduce the chances of a tipping force being applied to the casting. Having the patient bite on cotton rolls (Fig. 17–20D) can also be used to apply force and is particularly useful in maintaining force on the prosthesis while the cement hardens.

Excess cement should be left on the margins while the cement sets in order to prevent moisture from contacting the cement at the margin. Cotton rolls and gauze squares should be positioned so that excess saliva is absorbed (Fig. 17–21). A rubber dam can be used during the cementation of some restorations to prevent moisture contamination of the marginal cement as it sets.

*Cooley Four Crown Seater, H. J. Bosworth Company, Skokie, IL 60076.

CEMENT REMOVAL

With the exception of resin cement, the excess should not be removed until the cement has set completely. An explorer or small spoon excavator is used to fracture away the hardened cement (Fig. 17–22). The gingival crevice and interdental areas should be carefully inspected with an explorer to be sure all remnants of cement have been removed from the soft tissue and that effective oral hygiene procedures have been made possible (Fig. 17–23). Dental floss is then passed through proximal contacts and underneath and around pontics, to remove any cement left in these areas (Fig. 17–24).

Any cement retained on occlusal surfaces should be removed because it can prevent proper interdigitation of the teeth and final evaluation of occlusal contact. Intraoral and extraoral soft tissues should be cleaned so the patient leaves in a condition that is cosmetically and biologically acceptable.

FINAL INSPECTION

Following cleanup procedures, final evaluation of the prosthesis is performed. Complete seating should be verified visually on accessible margins and through the use of a sharp explorer. The occlusion is rechecked, and any postcementation refinements are completed. Final marginal finishing can be accomplished by using fine-

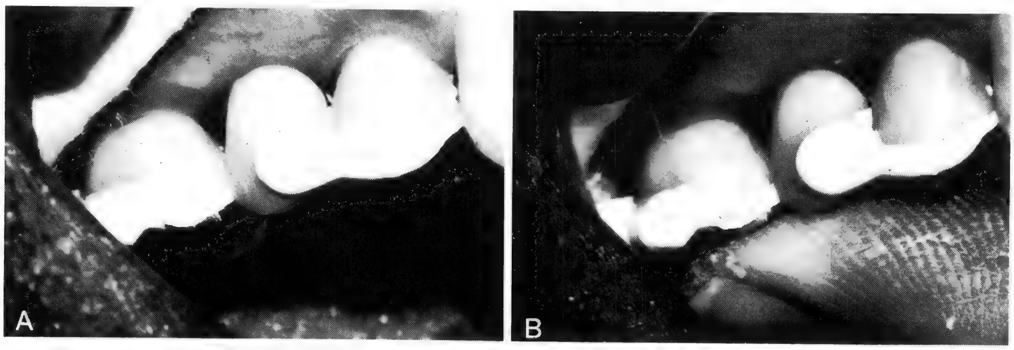


FIGURE 17–19

A, Excess cement wiped away from mesiofacial margin of molar retainer.
B, Additional seating pressure expresses more cement. This procedure is repeated until no more cement can be forced from under the castings.

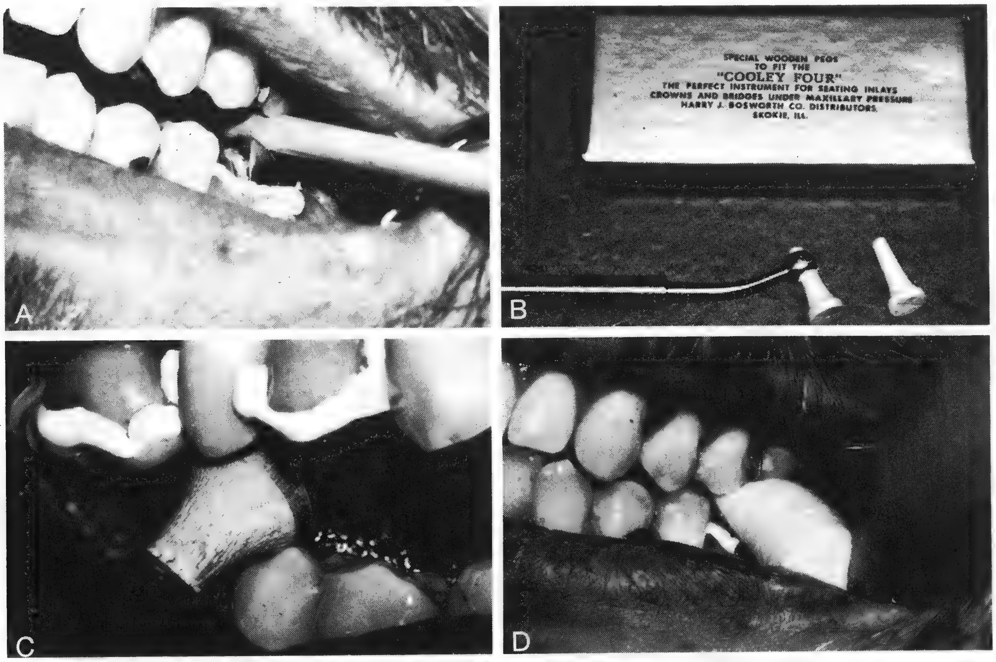


FIGURE 17–20

A, Patient biting on an orangewood stick to aid in expressing excess cement.
B, Cooley Four wooden pegs and metal handle.
C, Peg positioned between restoration and opposing tooth so patient's muscles can be used to facilitate seating.
D, Patient biting on a cotton roll while cement hardens.

FIGURE 17–21 Cotton rolls and gauze used to control moisture as cement hardens around maxillary lateral incisor restorations.

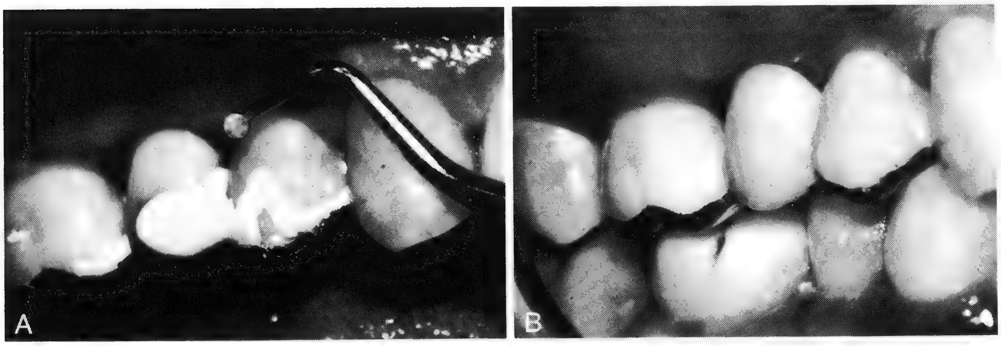


FIGURE 17–22

A, Small spoon excavator used to remove excess cement.
B, All cement removed.

FIGURE 17–23 Cement removed interproximally with an explorer.

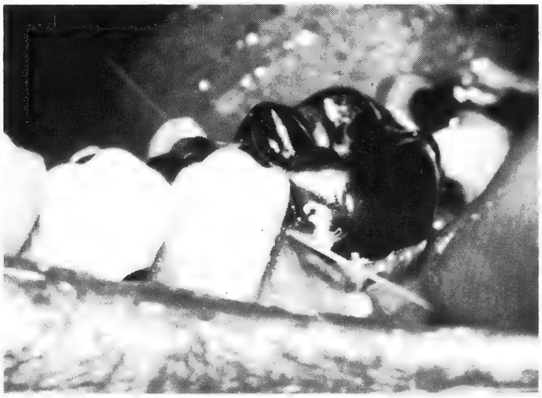


FIGURE 17–24 Dental floss placed subgingivally to aid in cement removal.

grit abrasive discs or fine-grit stones. Any adjusted areas are polished using flour pumice and a rubber cup (Fig. 17–25), which can be followed by a tin oxide lustre-producing agent. The restoration must exhibit a highly polished surface and a smooth transition from casting to tooth (Figs. 17–26, 17–27).

Incomplete seating is not encountered if the cementation procedure is properly followed but can and does occur as a result of human oversights. When this is

FIGURE 17–25 Rubber cup and flour pumice used to polish casting after marginal finishing.

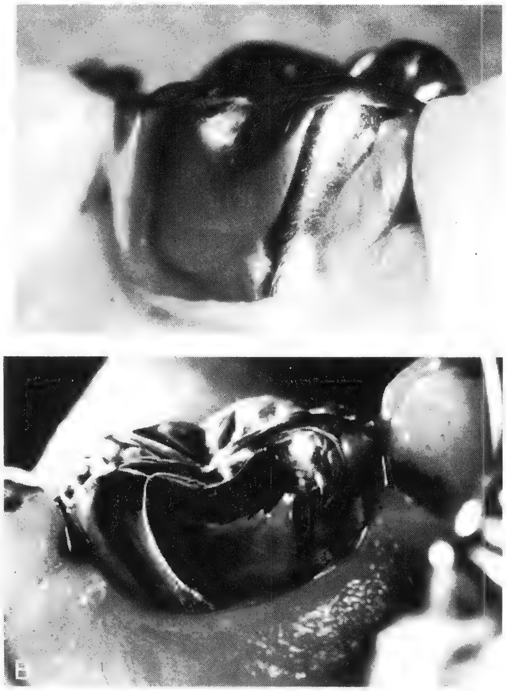


FIGURE 17–26

A, Facial view of mandibular molar full veneer crown.
B, Lingual view.

observed, an attempt should be made to remove the restoration as soon as possible, while the cement is still weak. With proper preparation form and casting adaptation, it is unlikely that the casting can be removed intact. Nevertheless, successful postcementation removal can occur and is worth an attempt. This is done by tapping along the long axis of the preparation. A straight chisel and mallet are judiciously used for this process. The chisel should engage the casting away from the margin in an area in which the chisel gouge can later be removed by polishing should the restoration be successfully unseated (Fig. 17–28). Commercial crown removers* are available that can sometimes be placed under pontics or connectors and be successfully used without damage to the prosthesis (Fig. 17–29). When these attempts are not successful, the restoration re-

*Morrell Crown Remover, Misdom-Frank Instrument Company, New York, NY 10003.

FIGURE 17–27 Occlusal view of mandibular fixed partial denture and single full veneer crown.

FIGURE 17–28 Straight chisel and mallet being used to carefully tap parallel with the path of insertion.

quires sectioning in order to achieve removal. This is best accomplished by grinding through the casting from the finish line to the occlusal surface using a crosscut bur (a number 700) with a copious water spray. This procedure produces a slot in the casting into which a flat-bladed instrument is placed (Fig. 17–30). When a twisting motion is applied to the instrument, it creates leverage that bends the metal laterally out of contact with the prepared tooth without damaging the tooth. The reader should refer to Chapter 29 for more details of this procedure.

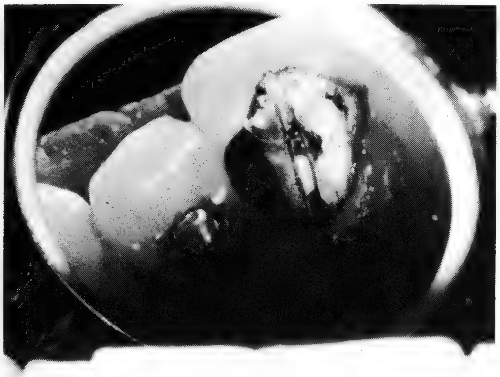


FIGURE 17–30 Completed slot produced using a number 700 bur. A thin-bladed instrument can be placed into the slot so that when twisted it expands the circumference of the restoration.

HOME CARE INSTRUCTIONS

Every patient should receive instructions regarding proper brushing (Fig. 17–31A) and flossing (Fig. 17–31B) of restorations. In addition, the use of aids for passing floss under pontics and connectors (Fig. 17–32) and the use of an interproximal brush (Fig. 17–33) should be demonstrated on the cemented prosthesis. Oral hygiene aids should be provided to the patient or information given as to where these items can be obtained. The relationship of oral hygiene to the health of the surrounding tissues, and thus the longevity of the prosthesis, *must* be emphasized.

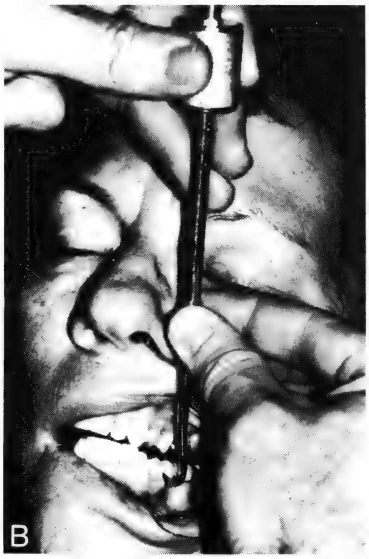


FIGURE 17–29

A, Two types of tips for crown remover.
B, Instrument tip placed under connector. Shaft is held paralled with path of insertion while cylindric weight is quickly raised along shaft until it hits cap at top of shaft and creates a sharp tap.

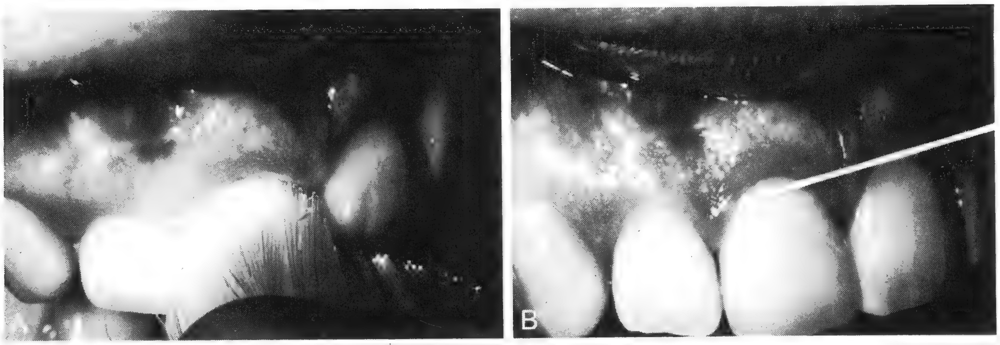


FIGURE 17–31

A, Proper brushing of cervical margin being demonstrated to patient.
B, Use of unwaxed dental floss to reach subgingivally on distal surface of restoration.

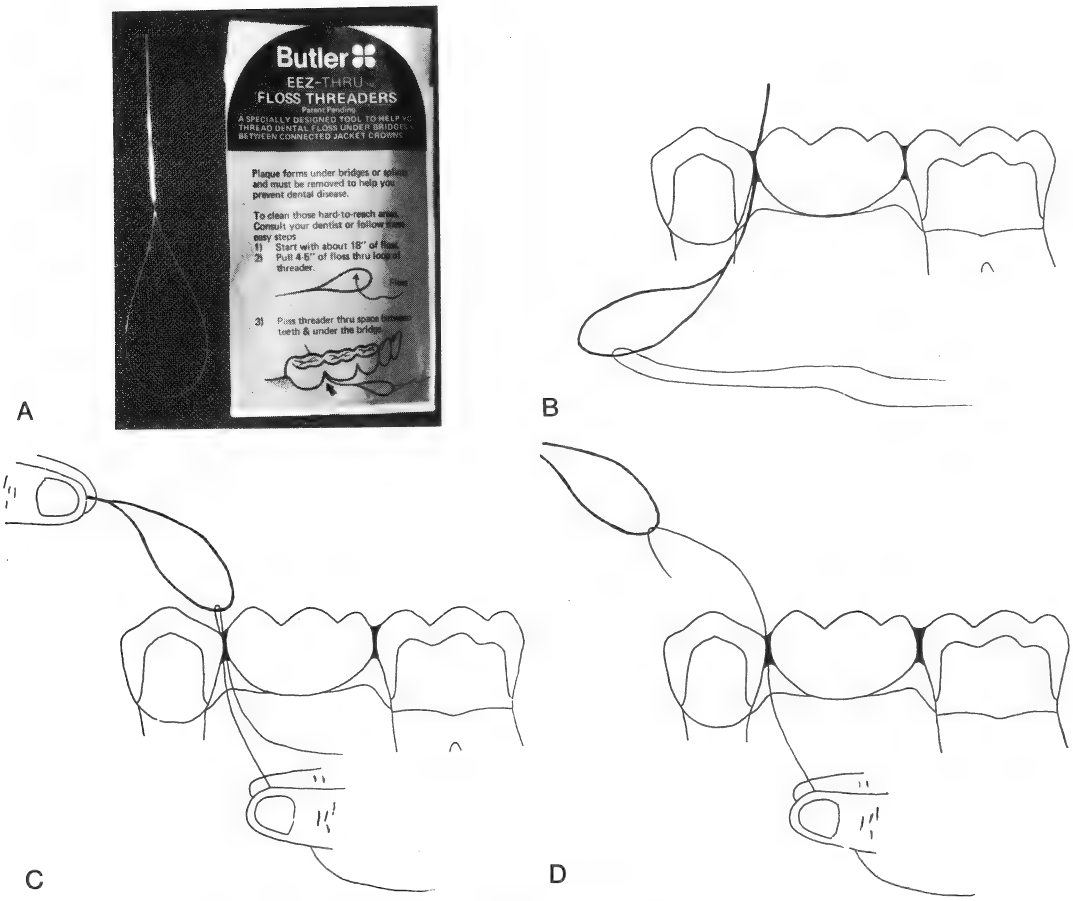


FIGURE 17–32

A, Looplike floss threaders used to pass floss under connectors.
B, Floss is threaded inside plastic loop and then tip of loop is placed under connector.
C, D, While one end of the floss is held, the loop is pulled completely under the connector along with other end of the floss.

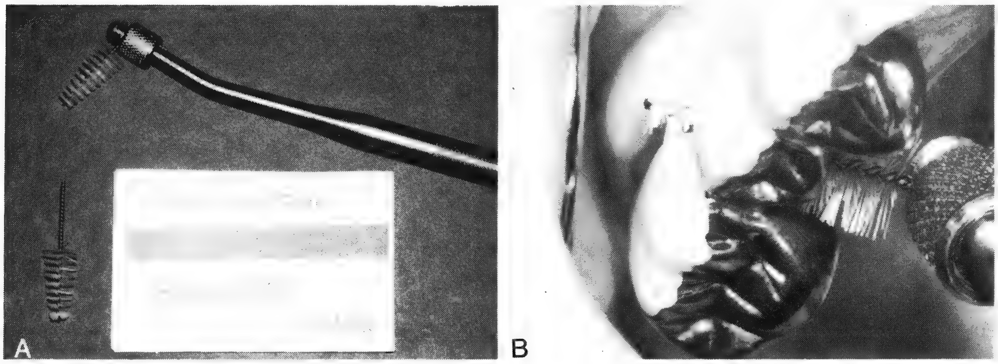


FIGURE 17–33

A, Butler Proxabrush with number 614 conical brush.
B, Brush being passed under distal connector.

POSTINSERTION CARE

Patients receiving restorations should be observed after normal functional activity has occurred and ideally during the first few days following cementation. The patients may occlude slightly differently under normal chewing conditions and without the presence of local anesthesia. A postinsertion appointment allows the detection and adjustment of any interfering centric or eccentric occlusal contacts before problems arise. This time also allows for evaluation of the effectiveness of home care and other symptoms that the patient may manifest. Generally, postinsertion observations should continue on gradually extended time intervals until at least one visit has occurred without the need for additional adjustment or home care instructions. Patients should be advised to call if any untoward symptom occurs prior to the next periodic examination.

18

Postinsertion Problems

The clinical procedures involved in fabrication and insertion of a fixed partial denture can elicit a variety of responses from the dental pulp, periodontal tissues, and associated anatomic structures. Some of the pulpal and periodontal responses are considered to be normal because they are encountered frequently and exist only for a limited time without producing serious problems. Other responses indicate major problems or the need to provide additional treatment in order to avoid severe complications.

The potential for irreversible pulpal damage exists each time a tooth is prepared, but a healthy pulp usually withstands the trauma, and only minimal temporary side effects are manifested. However, failure to follow biologically correct procedures for tooth reduction, temporary restoration fabrication, adjustment and cementation of the final restoration, or postinsertion care may result in discomfort to the patient or the need for endodontic treatment. Even with the use of proper technical procedures, the need for endodontic treatment may arise if the pulp is unhealthy but asymptomatic from previous trauma, caries, or dental treatment. The same principles that govern the health of the pulpal tissues apply to the periodontal tissues.

SYMPTOMS

Thermal Sensitivity

Pulpal discomfort from temperature change is frequently encountered following cementation of fixed partial dentures. This results from the removal of enamel and dentin, which have insulating properties, and their replacement with metal, which is an excellent thermal conductor.

Some sensitivity to cold following insertion of a cast restoration is generally encountered and is considered to be a normal response. The duration of this effect ranges from a few days to several months before all sensitivity ceases. The magnitude and duration of this sensitivity are increased when the preparation is in close proximity to the pulp. When caries removal approaches the pulp, an insulating base material should be placed over the deep portion of the preparation to decrease the subsequent effect of thermal diffusion through the metal casting and the irritating effect of liquids that are present in certain cements such as zinc phosphate. Thermal diffusion through a substance is related to the thermal conductivity of the material as well as its thickness. Thus, the base must be used in a minimal layer of approximately 0.5 mm to provide protection. Failure to use copious amounts of water spray during the bulk reduction of the tooth and prolonged dry cutting also increase the potential for postinsertion sensitivity.

Other procedures that cause sensitivity during treatment and that have been found to increase postinsertion sensitivity to cold include (1) failure of the temporary restoration to cover all prepared tooth surfaces, (2) a loose temporary restoration that allows seepage of oral fluids over the prepared surfaces, or (3) a temporary restoration that places excessive occlusal forces on the prepared teeth.

Prolonged sensitivity to cold that does not decrease in severity with time or acute pain that becomes unbearable to the patient indicates the need for endodontic treatment.

The presence of short-term sensitivity to heat can be caused by the same factors that cause cold sensitivity and is considered normal. Prolonged or acute sensitivity to heat indicates the need for endodontic therapy.

Discomfort During Function

Pain experienced when occlusal forces are applied to the prosthesis during chewing are often caused by premature centric occlusal contact or excessive contact during eccentric mandibular movements. Occlusal adjustment of the offending area provides relief from the pain. Tenderness to percussion can also result from heavy centric or eccentric occlusal contact. If the faulty occlusion is detected and adjusted, there is relief from the pain. Occlusal discrepancies that are not corrected may lead to irreversible pulpal damage The presence of tenderness to percussion or biting forces in the absence of occlusal discrepancies often indicates the need for endodontic treatment.

A tooth that has been out of occlusal function for a long time may initially exhibit discomfort during function when placement of a prosthesis brings it back into normal function. With time, the tooth adjusts to the increased functional activity.

Gingival Inflammation

Usually, some gingival irritation is caused by the clinical procedures performed in conjunction with a fixed partial denture, but if those procedures are carefully executed and the patient maintains good oral hygiene

throughout the treatment, the effect is minimal and the soft tissue rapidly returns to normal.

Inflammation that manifests itself after cementation of the final prosthesis probably is related to faulty cervical contour, marginal fit, or embrasure form of the prosthesis. It also could be related to inadequate oral hygiene instruction by the dentist or poor implementation on the part of the patient. The inflammation may be not only a response to the final prosthesis but also could be the cumulative effect of trauma from several previous aspects of treatment.

Aspects of treatment known to create excessive gingival inflammation include soft tissue removal with rotary instruments, excessive tissue retraction, a rough or poorly fitting temporary restoration, or failure to completely remove remnants of the impression material or temporary cement from the gingival sulcus.

Retention of Food

The collection of food around pontics and connectors or the adherence of certain foods to the prosthesis cannot be avoided. However, proper instruction in the use of oral hygiene aids the patient in removing the foreign material and preventing breakdown of the periodontal tissues.

The frequent impaction of food between an abutment retainer and adjacent teeth can be caused by either poor occlusal relationships or lack of adequate proximal contact. A cusp from the opposing dentition can occlude with adjacent marginal ridges in such a way that it forces the teeth apart and wedges tough or stringy food interproximally. When this problem exists, the offending cusp should be recontoured to reduce the wedging effect. A proximal contact that is missing or poorly located can cause food impaction, even during the chewing of normal foods. It is also possible for a properly constructed proximal contact to open following cementation of a prosthesis. This condition is most commonly the result of heavy occlusal contact causing tooth movement in response to the interference. Also, a lack of occlusal contact may allow eruption to occur with a resulting loss of proximal contact.

Trauma to the Cheek or Tongue

The cheek or tongue can be irritated by contact with sharp areas or poorly polished portions of a prosthesis.

Biting of the cheek or tongue may occur during chewing as a result of the placement of pontics in areas in which the tongue and cheek were previously not restricted from entering. Generally, this problem is only temporary and diminishes when the muscles are retrained.

Another cause of cheek or tongue biting is a cusp-to-cusp or end-to-end occlusal relationship without normal horizontal overlap. Horizontal overlap of the teeth prevents soft tissue from being caught between the occlusal surfaces and being injured during chewing. When this type of occlusion is unavoidable, it may be necessary to blunt the cusp tips to avoid trauma.

Sensitivity to Sweets

Postinsertion discomfort from sugar-containing foods can be caused by failure of the final prosthesis to completely cover all prepared tooth surfaces. Sweet sensitivity is also encountered when a significant portion of the luting agent has undergone dissolution or if an abutment retainer is loose. When these conditions are encountered, a new fixed partial denture should be fabricated.

A carious lesion present on an abutment tooth, or in the immediate area, may also produce sensitivity to sweet foods.

Tooth Mobility

Mobility in a prosthesis can be caused by a poor occlusal relationship that produces heavy centric occlusal contact or particularly by eccentric occlusal interferences. The overloading of the prosthesis causes change in the periodontal ligament and supporting bone, thus allowing excessive movement. Occlusal adjustment eliminates the excessive force and usually reduces the mobility to a normal level.

When there is inadequate osseous support, mobility of a prosthesis can exist even in the absence of excessive occlusal forces. Mobility of this nature can be a serious problem if it continues to increase owing to the combination of forces applied and the lack of adequate bone support for the fixed prosthesis. A removable partial denture may then be necessary in order to provide bilateral bracing for the weakened teeth by attaching the removable prosthesis to additional abutment teeth in other areas of the arch.

Neuromuscular Discomfort

Neuromuscular discomfort caused by a fixed prosthesis must be considered a serious problem, and corrections must be implemented immediately. Pain in the temporomandibular joint or associated muscles can be related to improper occlusion created by a fixed prosthesis. This type of discomfort following insertion is most commonly caused by occlusal contact on the prosthesis, which does not allow the remainder of the teeth to contact in the normal manner. In order to avoid the interfering occlusal contact and bring other teeth into occlusion, muscular contraction guides the mandible to a different position. The new mandibular position can create neuromuscular pain in some patients as a result of positional changes in the ligaments and muscles associated with the temporomandibular joint.

It must be recognized that other factors may cause pain of this nature, and relief may only be found outside the field of occlusion.

Nonspecific Complaints

Some patients may not have a specific complaint of pain but are aware that the prosthesis is present and that something feels different or slightly uncomfortable. This discomfort could be from the additional force applied to the abutment teeth, a slight occlusal discrepancy, or simply the presence of an artificial tooth occupying a previously open area.

Other nonspecific complaints may be related to some aspect of the prosthesis that the patient does not like (such as esthetics) but is reluctant to discuss. Financial aspects (concern over the cost) have been known to produce nonspecific complaints.

19

Introduction to Dental Ceramics

Full-coverage ceramic restorations have been used in dentistry since the late 1800s and early 1900s when the porcelain jacket crown was developed. This *all-ceramic restoration* proved to be the most esthetic full-coverage restoration available to dentistry. However, the need for greater strength and versatility led to the development of a restoration having porcelain fused to a metal substructure. Metal helps the procelain to resist fracture, and a stronger restoration is produced. The *metal-ceramic crown* is the most widely used full-coverage restoration in the current practice of dentistry. Other commonly used names for this restoration include *porcelain-fused-to-metal crown, ceramometal crown,* and *bonded porcelain veneer crown.*

Both types of ceramic crowns, all-ceramic and metal-ceramic, have advantages, and an understanding of their indications and contraindications is essential to optimize their use. However, the first consideration that must be made is whether either type of ceramic restoration is indicated over the more conservative partial-coverage crown. Esthetically, a ceramic restoration is often the best choice, but sometimes the esthetic advantages are outweighed by the biologic consequences. Also, under certain circumstances, partial-coverage restorations may produce better biologic and esthetic results.

CONSIDERATIONS REGARDING FULL COVERAGE AND PARTIAL COVERAGE

Patient Age and Pulpal and Periodontal Considerations

Ceramic restorations generally should not be used in young patients. The large pulp size encountered during childhood and adolescence does not permit removal of sufficient tooth structure to achieve an esthetic thickness of porcelain without pulpal damage or gross overcontouring. Resin restorations should be used as a temporary solution whenever possible to allow time for secondary dentin formation and pulpal recession. In this way, future tooth reduction for a ceramic restoration is not as likely to produce irreversible pulpal damage.

Even when potential pulpal injury is not a concern (for example, on endodontically treated teeth), there are reasons for restricting the use of ceramic restorations in adolescents. In order to achieve adequate retentive length, a subgingival finish line is often required, which can contribute to poor tissue health, particularly in the presence of less than optimal oral hygiene. Poor tissue health may be manifested by gingival recession, or there may be inflammation that interferes with the apical repositioning of the gingival tissue that normally occurs during the transition from adolescence to early adulthood. Both situations often lead to a permanent esthetic problem.

If full-coverage ceramic restorations are necessary in young patients, the margins should be located supragingivally whenever this is possible in order to reduce these potential soft tissue problems.

With adult patients, there is less chance of producing irreversible pulpal damage with ceramic restorations, but the potential is still greater than that encountered with partial-coverage preparations, with which the amount and depth of tooth reduction is less.

Condition of Tooth

Often teeth requiring crowns have been extensively damaged or have large existing restorations, and a full-coverage restoration is indicated. A ceramic restoration is the first choice when this situation exists in a visible area of the mouth.

However, when intact abutment teeth are present, the routine use of full-coverage retainers is inconsistent with a conservative approach to fixed prosthodontics. Often these teeth can be esthetically restored with partial-coverage restorations and almost always with less pulpal and periodontal trauma.

Tooth Form and Alignment

The coronal morphology of some teeth with short axial walls may not allow for satisfactory retention when they

are prepared for full-coverage restorations. A notable example is the type of maxillary canine the incisal edge of which possesses long mesial and distal slopes that terminate at the level of the interdental gingival tissue. In this situation, a pinledge using pins to provide intracoronal retention may provide the most satisfactory result.

Thin anterior teeth are poor candidates for full coverage, since the incisal aspect lacks sufficient faciolingual thickness for adequate reduction of the labial and lingual surfaces. For example, when the lingual surface of a thin incisor is reduced to provide an adequate thickness of restorative material, the remaining tooth structure does not allow adequate facial reduction for an esthetically acceptable restoration. If both surfaces were sufficiently reduced, the result would be encroachment upon the pulp, a loss of incisocervical preparation length, or both.

Abnormal axial alignment of abutment teeth can lead to pulpal damage when full-coverage restorations are used. An example would be one abutment tooth in normal arch alignment and the other exhibiting facioversion or significant mesial tipping. Producing a path of insertion with full-coverage preparations results in excessive axial reduction of the malpositioned tooth and potential pulpal damage. A partial-coverage preparation can sometimes be designed that avoids a surface in which reduction would damage the pulp.

Wear and Habits

Extensively worn teeth generally indicate the presence of excessive occlusal forces from functional activity or oral habits such as bruxism. Ceramic restorations often fail prematurely under these conditions, whereas the use of partial-coverage restorations, when possible, provides greater fracture resistance. Also, if porcelain is in contact with opposing teeth, there is greater wear of these teeth than would occur if partial-coverage metal restorations were used.

After the previous considerations have been reviewed, many clinical situations still require the use of full-coverage ceramic restorations, and a decision must be made whether to utilize the porcelain jacket crown or the metal-ceramic restoration.

INDICATIONS FOR THE PORCELAIN JACKET CROWN

The porcelain jacket crown is indicated when an optimal esthetic result is desired. From the standpoint of longevity, this restoration is best suited for restoring maxillary or mandibular incisor teeth (Fig. 19–1). Jacket crowns are sometimes used on canines but are more prone to fracture, owing to the functional activity occurring in these areas of the mouth.

CONTRAINDICATIONS TO THE PORCELAIN JACKET CROWN

Experience has shown that the situations described here tend to promote premature fracture of porcelain jacket crowns.

FIGURE 19–1 Maxillary left central incisor traumatically injured during adolescence and restored with resin. Patient's age and pulp size now permit placement of ceramic restoration. Esthetic demands indicate a porcelain jacket crown.

Tooth Form

In order for a porcelain jacket crown to be successful, the completed preparation must provide support for the restoration so that it can effectively resist occlusal forces.

When teeth with short clinical crowns are reduced incisally to provide space for translucent porcelain, the preparations often do not possess enough length to adequately support an all-ceramic restoration. The preparation for a jacket crown should be minimally two-thirds the length of the final restoration. A preparation that is three-quarters the length of the final restoration is more nearly ideal (Fig. 19–2). When this length relationship cannot be maintained, a porcelain jacket crown is contraindicated because of the faciolingual tipping forces that are not adequately resisted by the incisal aspect of the preparation.

When shovel-shaped incisors or teeth with small cingula are prepared for porcelain jacket crowns, they often do not have sufficient lingual wall length to properly support and retain the restoration.

An incisor that is thin labiolingually does not lend itself to a porcelain jacket crown, since a good color match requires adequate facial reduction, and the amount of lingual reduction cannot be compromised

FIGURE 19–2 Discolored tooth prepared for porcelain jacket crown. After incisal reduction, the preparation possesses adequate length to support an all-ceramic restoration.

FIGURE 19–3 Round overtapered teeth, which contraindicate porcelain jacket crowns.

without weakening the restoration. A better choice is the metal-ceramic crown, which can be sufficiently strong under conditions of decreased lingual reduction, owing to the use of a metal substructure.

Certain tooth forms (such as peg-shaped teeth) produce preparations that are round in cross section or more axially tapered than is usual (Fig. 19–3). These types of preparations do not afford good resistance against rotation of the restoration on the prepared tooth. Such rotational tendencies cause tensile forces to be developed, which are poorly resisted by all-ceramic restorations.

Occlusal Relationship and Forces Present

With normal anterior tooth alignment, the resistance of a porcelain jacket crown to occlusal forces is more favorable on mandibular incisors than on maxillary incisors. As food is chewed, force from the maxillary incisors compresses a mandibular restoration against the prepared tooth. Compressive forces are well resisted by all-ceramic restorations.

While porcelain jacket crowns are commonly placed on maxillary incisors, the forces involved are not as favorable, and the location of centric occlusal contacts with the mandibular incisors is an important consideration. Contact of the restoration with the mandibular incisors should be located over the concave portion of the prepared lingual surface of the maxillary incisor (Fig. 19–4A). This is the area between the incisal edge and the cingulum of the preparation. Forces applied here are largely compressive in nature and are resisted well.

When centric occlusal contact occurs incisally to the prepared tooth, the crown attempts to tip facially, having a fulcrum on the incisal edge of the preparation (Fig. 19–4B). This creates tensile forces in the facial porcelain, which increase the potential for fracture.

Occlusal contact located cervically to the cingulum also places tensile and shear forces on the ceramic material (Fig. 19–4C). Because of the mesiodistal convexity of the preparation in this area, force applied by the mandibular incisors tends to shear away the lingual cervical porcelain rather than to compress it against the prepared tooth.

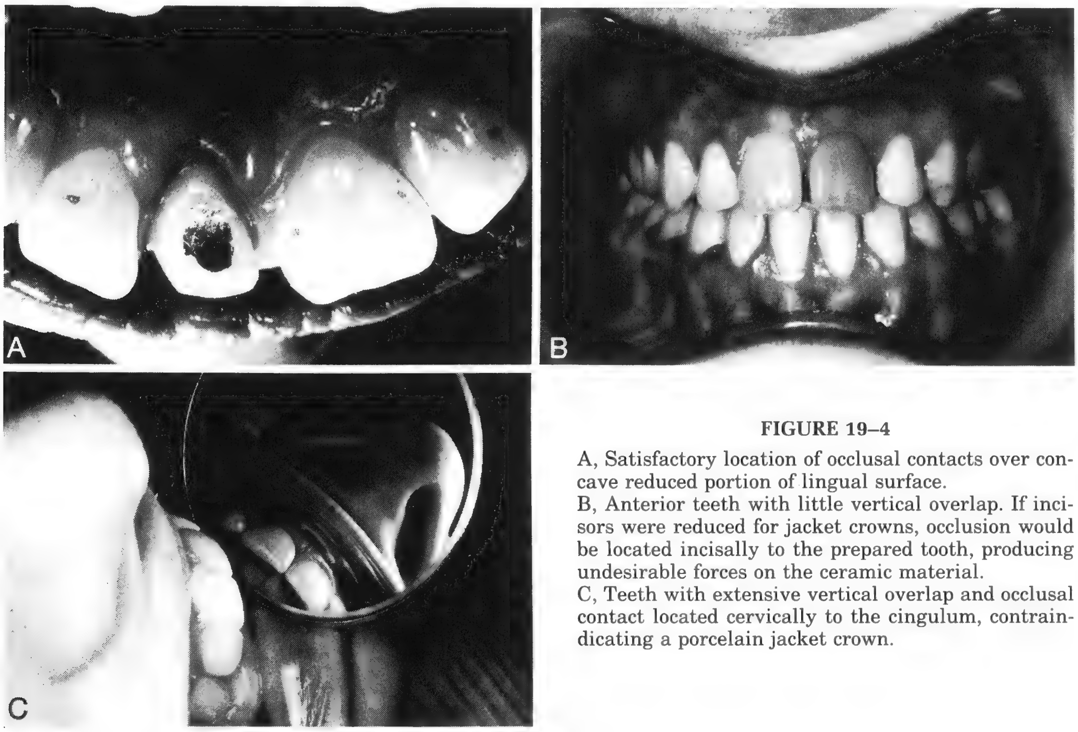


FIGURE 19–4

A, Satisfactory location of occlusal contacts over concave reduced portion of lingual surface.
B, Anterior teeth with little vertical overlap. If incisors were reduced for jacket crowns, occlusion would be located incisally to the prepared tooth, producing undesirable forces on the ceramic material.
C, Teeth with extensive vertical overlap and occlusal contact located cervically to the cingulum, contraindicating a porcelain jacket crown.

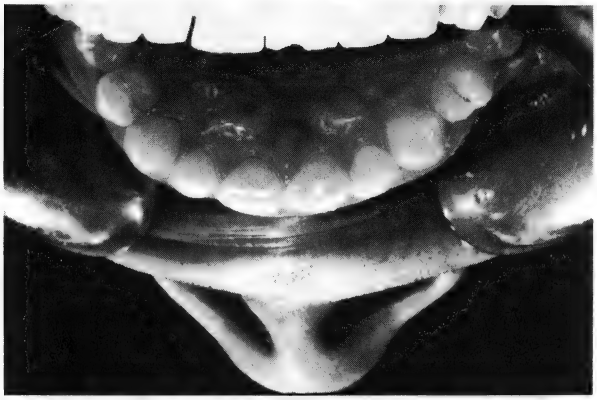


FIGURE 19–5 Anterior teeth needing restorations because of wear from bruxism; all-ceramic restorations are contraindicated.

FIGURE 19–6 Wear and chemical erosion have extensively damaged several teeth. Esthetic requirements indicate use of ceramic restorations; metal-ceramic crowns have the best chance of withstanding heavy occlusal forces.

An edge-to-edge relationship of the maxillary and mandibular incisors places favorable compressive forces on the restoration and does not contraindicate porcelain jacket crowns. If a shoulder finish line has been established and the incisal edge is not excessively sharp, this occlusal relationship compresses the restoration against the flat shoulder, and adequate support is provided by the preparation. In addition, the usual tipping forces exerted during protrusive mandibular movements are considerably reduced in an edge-to-edge incisor relationship.

Porcelain jacket crowns are contraindicated in patients who exhibit strong active oral musculature, as evidenced by clenching or bruxing habits (Fig. 19–15). A pipe smoker places excessive forces on the teeth where the pipe is held and all-ceramic restorations should not be used in this area of the mouth.

Patient Lifestyle

Porcelain jacket crowns should not be used for patients for whom trauma is likely to occur from occupational or recreational endeavors such as contact sports.

INDICATIONS FOR THE METAL-CERAMIC CROWN

Clinical conditions for which an esthetic result is required but the forces are not favorable for a porcelain jacket crown indicate use of a metal-ceramic crown.

Teeth that are short, round, tapered, or lack a well-developed cingulum are more satisfactorily restored with a metal-ceramic restoration than with a porcelain jacket crown. Additional resistance and retention form can be achieved through a metal substructure adapted to auxiliary grooves or pinholes in the preparation.

A metal-ceramic crown is more resistant to fracture in patients with habits and lifestyles that place heavy occlusal forces on the restoration (Fig. 19–6).

Removable partial denture abutment retainers are best handled with metal-ceramic restorations.

CONTRAINDICATIONS TO THE METAL-CERAMIC CROWN

Metal-ceramic crowns are contraindicated when the teeth can be satisfactorily restored with a more conservative restoration.

GUIDELINES FOR HANDLING PORCELAIN IN THE LABORATORY

Prior to the detailed discussion of laboratory fabrication procedures for porcelain jacket and metal-ceramic crowns in the subsequent chapters, it is appropriate to discuss guidelines for proper handling of the porcelains for both types of restorations.

Ceramic restorations are fabricated by forming the shape of a tooth with porcelain powders that resemble finely ground sand. The powder is mixed with a liquid until a consistency is achieved that allows the mixture to be applied with an instrument to the desired thickness and shape. The applied porcelain is then dried and fired in an oven until the powder particles fuse, producing a glass or enamel that resembles tooth structure.

A metal-ceramic restoration is formed by fusing different porcelains over a relatively thin metal casting. First, a thin layer of opaque porcelain is applied over externally visible areas of the casting to mask the metal color. The casting is heated in an oven until the opaque coating fuses to the casting and a bond is achieved. Appropriately colored dentin and enamel porcelains are then applied and fired over the opaque layer until a slightly oversized crown form is achieved. The final shape is produced by using abrasive stones and diamonds to grind the fused material. The last step involves firing the shaped restoration until the porcelain surface flows slightly and a surface glaze is achieved.

Porcelain jacket crowns are formed in a similar manner except that different porcelain powders are used. They usually are formed and fired over a 0.001-inch thick platinum foil matrix, which is subsequently removed so that no metal is left in the final restoration. The first layer applied and fired is a high-strength core

porcelain, which provides the structural foundation for the all-ceramic restoration. Dentin and enamel porcelains are then fired on the core porcelain to achieve the final shape.

Dispensing and Mixing Porcelain

Porcelain powder settles in the container, and after long periods of storage it may be necessary to evenly redistribute the different particle sizes prior to dispensing the powder. Several end-over-end rotations of the container will remix the powder particles. The lid should not be removed immediately because smaller particles initially remain suspended in air and may rise out of the container and be lost.

The powder is generally dispersed onto a glass slab (Fig. 19–7) or a porcelain dish with individual compartments that contain the powders. If two or more different porcelains are mixed simultaneously on one glass slab, they must be kept separate and identifiable. It is a good idea to mark a piece of paper and place it under the glass slab or to place the respective bottles of powder immediately adjacent to each portion of porcelain so as to properly identify the mixes. Labels could also be attached to the slab or dish. In this way, there is less chance of confusing porcelains and inadvertently using the wrong material.

Porcelain can be mixed with distilled water or a special liquid medium. When mixed with distilled water, the porcelain dries out more rapidly and cannot be handled properly until the proper moisture level is reestablished. The manufacturer's special liquid or other available liquids inhibit drying and allow easier handling of the porcelain.

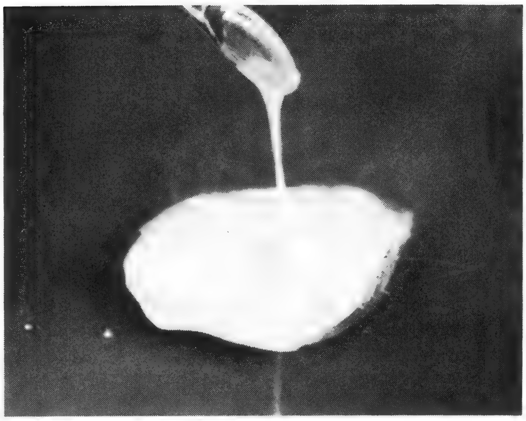


FIGURE 19–8 Porcelain mixed too thin.

The powder should be mixed to a consistency that retains some form when it is picked up with either a metal instrument or a brush (Fig. 19–7). Porcelain mixed too thinly does not hold its shape and slumps when an attempt is made to form the shape of a tooth (Fig. 19–8). When the trail left behind an instrument dragged through the mixture is quickly filled in with porcelain, this is a sign of too much moisture.

Mixed porcelain can also be too dry and so does not coalesce when one portion is added to another. When it is properly mixed, slight agitation or a patting motion

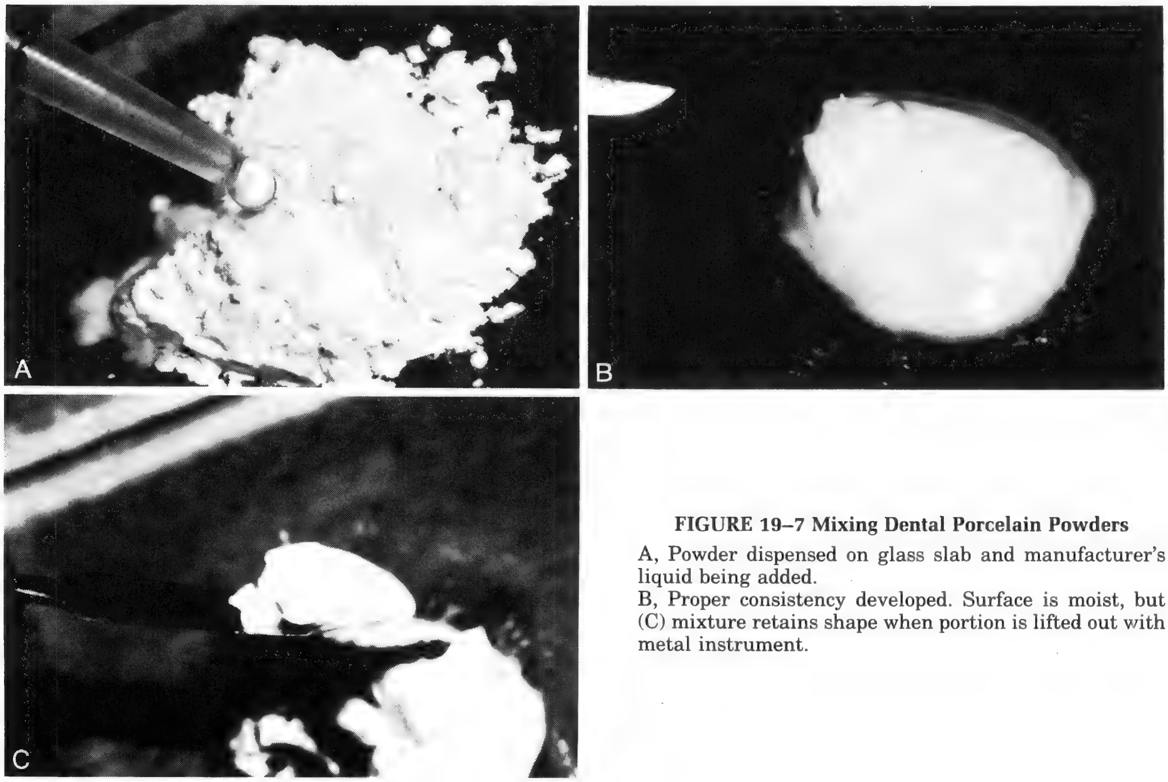


FIGURE 19–7 Mixing Dental Porcelain Powders

A, Powder dispensed on glass slab and manufacturer's liquid being added.
B, Proper consistency developed. Surface is moist, but (C) mixture retains shape when portion is lifted out with metal instrument.

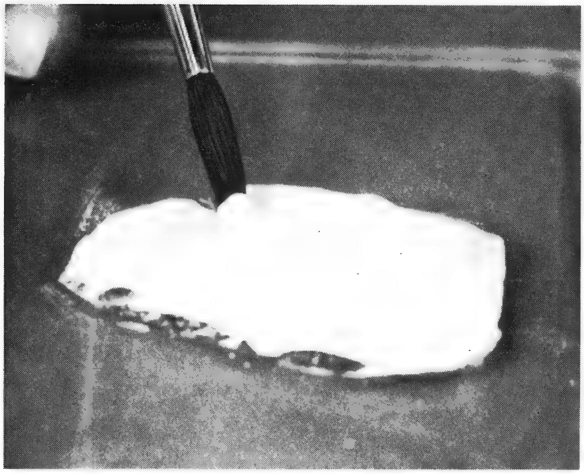


FIGURE 19–9 Porcelain being picked up with tip of moistened brush.

causes one increment of porcelain to unite with the other. Achieving a moisture level that is not too dry or too wet is one of the keys to successful manipulation of porcelain.

Applying Mixed Porcelain

Properly mixed porcelain can be applied with a brush or a metal instrument. The brush lends itself to better control over the addition of small amounts of porcelain, and its use is also more easily mastered by the novice.

Mixed porcelain is picked up with the tip of a moistened brush (Fig. 19–9) or metal instrument and placed in position. It is then pushed around with the same instrument until the desired thickness and form are achieved. All porcelain powders shrink when they are fired, so excess material must be applied to achieve the desired thickness in the fired state. The core porcelain for a jacket crown and the opaque porcelain for a metal-ceramic crown must be applied in relatively thin uniform layers, since excessive thickness adversely affects the color and depth appearance of the final restoration (Fig. 19–10). The amount of shrinkage of this thin layer is barely discernible, so only minimal excess material should be applied. Also, removing excess fired material while retaining uniform thickness and color is difficult and time-consuming.

Dentin and enamel porcelains are applied in greater thicknesses, since the majority of the color and depth come from these materials (Fig. 19–11). Their thickness results in a visually discernible firing shrinkage, which is best compensated for by application of enough excess material that a slightly oversized restoration is present after firing. The excess is easily removed by grinding when the restoration is shaped to its final form.

A mistake often made is to overdo the amount of excess dentin and enamel used so the crown is grossly oversized after it is fired. To achieve the final shape, extensive grinding is required, and often the outer layer of enamel porcelain is completely removed, so that the resulting restoration lacks translucency.

An absorbent material such as gauze or tissue paper should be readily available during application of increments of mixed porcelain so that excess moisture can be removed when necessary. Often the agitation produced when one increment of porcelain is added to another causes slumping, and the intricacies of the tooth form are lost. When slumping begins to occur, excess liquid rises to the surface, and the mixture starts to move. If an absorbent material is quickly brought into contact with the porcelain, excess moisture can be removed, and the shape can be retained.

Condensation

Condensation of porcelain involves packing the powder particles closely together prior to firing so that the fused material is as dense as possible to create the appearance of vitality and depth exhibited by natural teeth. The manufacturer aids this process by providing different sizes of powder particles to help reduce entrapment of air between the particles when they are condensed (Fig. 19–12).

Condensation is brought about by the rapid removal of excess liquid. It occurs as the surface tension of the

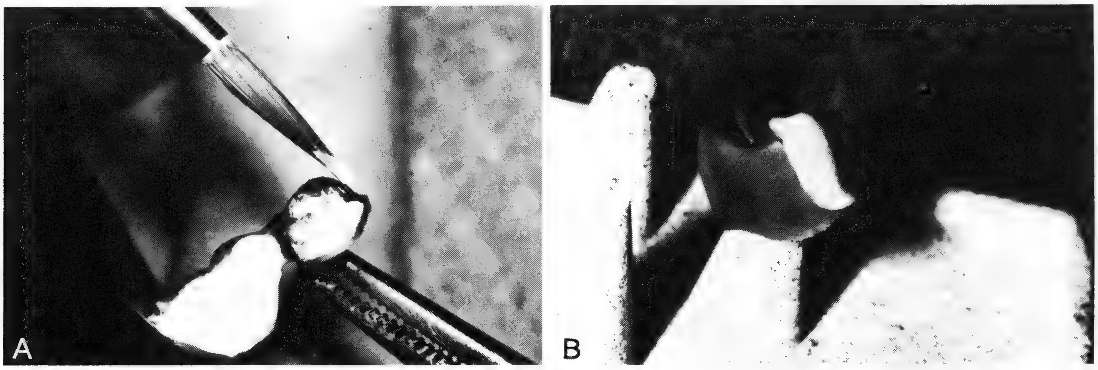


FIGURE 19–10 Applying Opaque Porcelain to Metal-Ceramic Crown

A, Mandibular premolar retainer being opaqued; molar completed.
B, Maxillary premolar after opaque has been fired. Note that a thin uniform layer was applied to allow space for dentin and enamel porcelains.

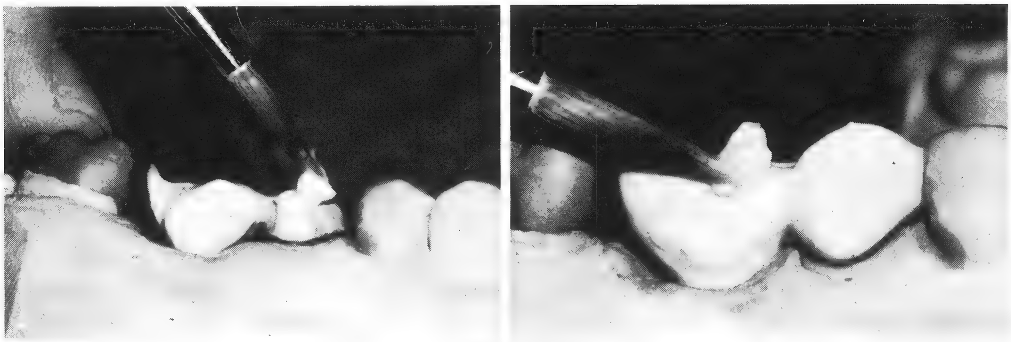


FIGURE 19–11
A, Large portions of dentin porcelain being applied (B) to establish slightly oversized restoration form.

exiting liquid packs the particles together. Removal of liquid is accomplished by promoting its accumulation at the surface of the porcelain, where an absorbent material can contact the liquid and draw it away. There are many methods of promoting rapid liquid removal. These are often described as different condensation techniques, whereas they really are different methods of facilitating liquid accumulation at the surface.

Holding the restoration firmly with a metal instrument, such as a needle holder or hemostat, and tapping the holding instrument with another metal instrument causes excess liquid to rise to the surface, from which it can be rapidly drawn (Fig. 19–13A, B). Serrations on the metal instrument can be rubbed across the holding instrument to set up vibrations that produce the same result.

Ultrasonic condensors and vibrating brushes are also available to facilitate removal of liquid.

The process of bringing liquid to the surface and then drawing it off is repeated until liquid fails to appear

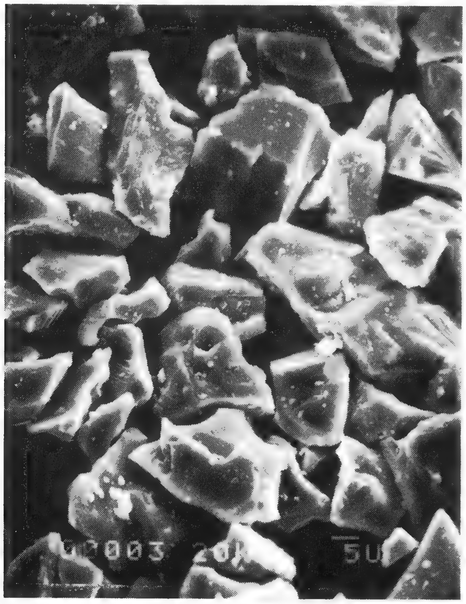


FIGURE 19–12 Scanning electron micrograph of porcelain powder showing different particle sizes. Magnification ×1000.

readily at the surface. Attempts at condensation beyond this point can actually disturb the packing of the particles as the mixture is beginning to dry.

Drying and Firing

Condensed porcelain must be completely dried before it is introduced to the high temperatures necessary to fuse the particles. Failure to eliminate residual moisture prior to firing results in the liquid's turning to steam inside the condensed porcelain mass. The steam causes an expansion, which explodes the compacted particles and destroys the established form, necessitating rebuilding and recondensing of new porcelain. A condensed restoration is generally dried by placing it on a firing tray and setting it in front of the open door of the furnace muffle (Fig. 19–13C). Holding the furnace temperature between 538 and 760° C (1000 and 1400° F) is suitable to dry most of the commonly used materials.

The drying time for condensed porcelain is directly related to its thickness. The relatively thin layers of opaque and core porcelain require about 2 to 5 minutes of drying. Thicker amounts of porcelain like that present in the initial buildup of a metal-ceramic or porcelain jacket crown require 10 to 20 minutes of drying.

Porcelain is fired in a vacuum to help eliminate air left after condensation procedures and to create a denser and more esthetically natural porcelain. The vacuum is applied while the restoration is still at the lower temperature. Porcelain begins to soften and fuse as the temperature goes above 540° C (1000° F), and the fusion continues to progress up to the manufacturer's recommended firing temperature. Extensive fusion of the surface porcelain, which softens first, can inhibit the subsequent removal of underlying trapped air if the vacuum is not activated until after surface fusion occurs.

When the desired fusion temperature is reached, the fired restoration is removed from the furnace and quickly placed under a protective glass cover, such as a beaker, to cool. The protective covering prevents any airborne contaminants from sticking to the still soft surface and also allows for slower, more uniform cooling of the restoration.

Storing Mixed Porcelain

While an application of porcelain is being dried and fired, the leftover mixed porcelain powders should be

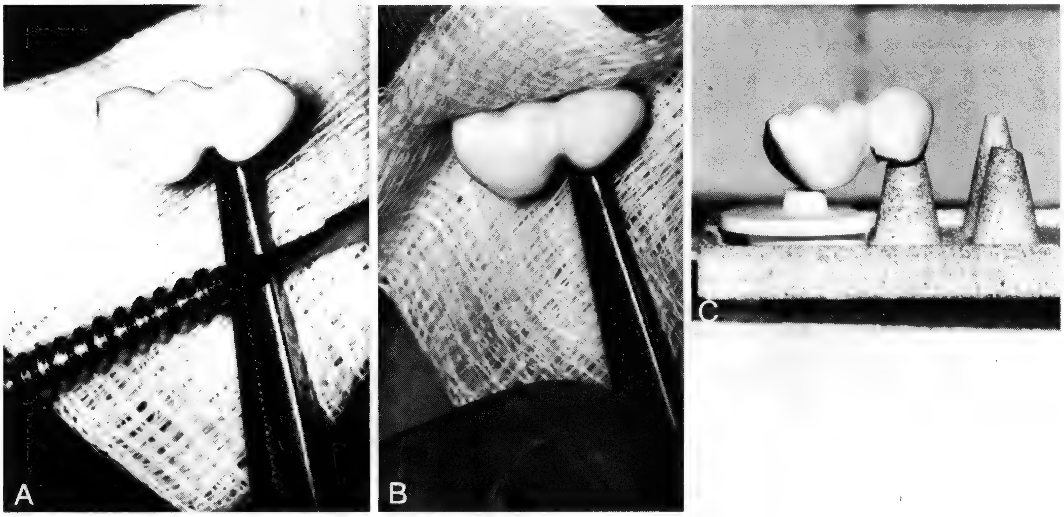


FIGURE 19–13 Condensation and Drying

A, Metal instrument being used to tap on hemostat, which grasps the casting. Note that moisture is rising to the surface.
B, Gauze is brought into contact with porcelain, thereby removing moisture and condensing particles.
C, Units placed on firing tray in front of open furnace and allowed to dry.

covered. This procedure helps prevent contaminants such as airborne particles of metal (particularly from alloys with lower specific gravity, which stay suspended in air for a longer time) from settling onto the mixed porcelain and creating dark specks when subsequent additions of porcelain are applied to finalize the restoration form. Defects of this nature have to be ground out when they occur in visible areas, and this necessitates an additional firing cycle. Because of this potential problem, a separate room for ceramics that is isolated from metal grinding areas is highly desirable, and ideally this room should have its own independent filtration and air handling system.

Additional Applications of Porcelain

Following cooling of the initial porcelain firing, the fused material should be inspected for shape (Fig. 19–14A). Ideally, there should be a slight excess of fired porcelain to allow shaping to the final form. Achieving this slight excess in all areas is rarely accomplished by the initial buildup and firing. Some correction in form, by the addition of more porcelain to selected areas, is generally necessary.

The leftover porcelain usually becomes dry and requires remoistening. Any remixing must result in the same consistency of material as is used in the initial mixture. If an error is to be made, the correction mixture should be thicker than the initial mixture. A problem related to additions of porcelain to the restoration, particularly for the novice ceramist, is that these areas do not blend well with the initial bake of porcelain and may look different from the previously fired porcelain. This result is most often caused by an increase in porosity in the additional application of porcelain. The increased porosity is caused by using a mix of a thinner

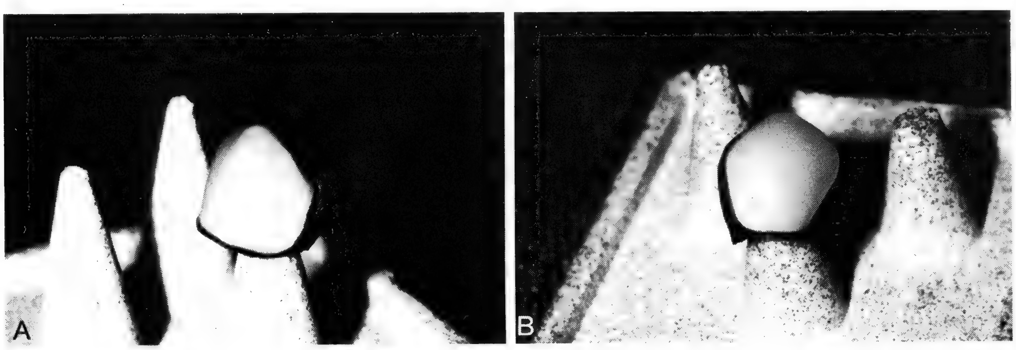


FIGURE 19–14

A, Premolar crown after initial firing. Note the deficient cervical contour.
B, Crown after second application and firing to achieve slightly oversized form.

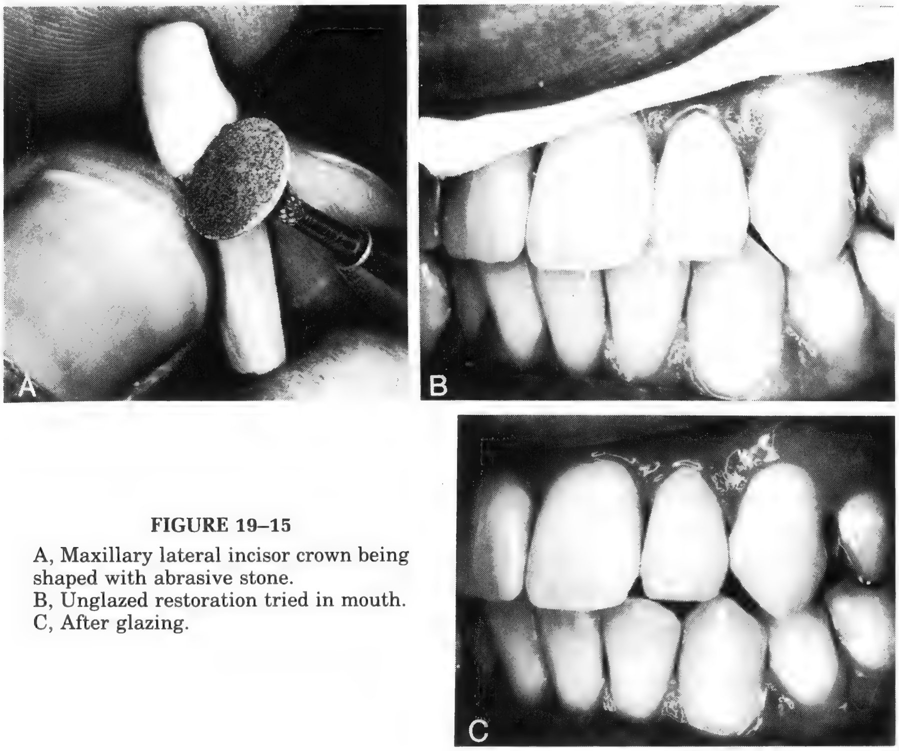


FIGURE 19–15
A, Maxillary lateral incisor crown being shaped with abrasive stone.
B, Unglazed restoration tried in mouth.
C, After glazing.

consistency, which cannot be condensed to the same density as the initial mix. This, coupled with liquid evaporation, can result in drying of the second application prior to complete condensation.

Additions of smaller amounts of porcelain require less drying time than the initial application. The porcelain is then refired according to the manufacturer's instructions in a vacuum and cooled as described (Fig. 19–14B).

SHAPING, CLEANING, AND GLAZING PORCELAIN

The fused porcelain is ground to its final shape by abrasive stones or diamonds (Fig. 19–15A). A set of instruments should be reserved for shaping ceramic materials and should never be used to grind metal. Instruments contaminated with metal and then used on porcelain often cause discoloration of the ceramic material when it is glazed.

The finally shaped restoration should be cleaned ultrasonically for 5 to 10 minutes in distilled water prior to glazing.

Porcelain is glazed in order to produce a surface that reflects light in a similar manner as do natural teeth and to establish a smooth surface that does not readily accumulate stains and from which plaque can be readily removed (Fig. 19–15B, C). Glazing can be done by either applying a thin surface layer of colorless porcelain powder and firing the material (*applied glaze* or *overglaze technique*) or by heating the ground porcelain to the point that the surface flows and becomes smooth and continuous *(autoglaze technique)*. The autoglaze technique is sometimes called a *natural glaze* and generally produces a surface more nearly resembling a natural tooth. A combination procedure of applying a layer of overglaze and heating to the point at which an autoglaze is achieved is also commonly used.

A glazed surface can be achieved either by firing the porcelain under a vacuum or in air. The procedure is commonly done without the use of a vacuum in order to avoid a problem that occurs occasionally when a vacuum is used. Porcelain restorations that have been shaped and are ready for glazing contain air that is trapped internally, although previous firings have been accomplished in a vacuum. The air bubbles are often not visible, but another vacuum firing could draw a bubble close to the surface without eliminating it. This poses an esthetic problem, which may necessitate grinding of the procelain to expose the bubble and then refiring of additional porcelain.

The glazing temperature is determined by the manufacturer of the porcelain. The required glazing time is related to the degree of surface gloss necessary to match the surrounding natural teeth and to certain handling factors. The rougher the surface, the longer is the required glazing time. A dense surface with few voids glazes more rapidly than a poorly condensed bubbly surface. The greater the number of previous firings, the longer is the firing time required to achieve the same degree of surface luster. Glazing time may involve simply bringing the restoration to the manufacturer's suggested glazing temperature and immediately removing the restoration or leaving it in the oven for 1 to 3 minutes. Experience with individual brands of porcelain, the degree of glaze required, and operator handling variables provides the information necessary to achieve the desired glaze.

20

Dental Ceramic Materials

DENTAL PORCELAINS

Dental porcelains are finely ground ceramic particles that are pigmented to provide colors that approximate natural tooth structure. The particles are mixed with a liquid until the mixture attains sufficient body that it can be formed into the shape of a tooth. The particles are condensed or densely packed together and fired at a high temperature, which fuses them together to form a translucent toothlike material. Dental porcelain is the most durable esthetic restorative material and, when correctly glazed, is easily cleansed of stain or plaque.

TYPES OF DENTAL PORCELAIN

Dental porcelain is generally classified into three different types according to its fusion temperature:

1. High-fusing: 1288 to 1371° C (2350 to 2500° F)
2. Medium-fusing: 1093 to 1260° C (2000 to 2300° F)
3. Low-fusing: 871 to 1066° C (1600 to 1950° F)

High-fusing porcelains are used to manufacture artificial denture teeth but rarely for tooth restorations. Medium- and low-fusing porcelains are used in the construction of all-ceramic restorations such as the porcelain jacket crown. A metal-ceramic crown utilizes low-fusing porcelain.

STRUCTURE AND COMPOSITION

Dental porcelains are in part crystalline minerals, such as quartz, dispersed in a noncrystalline silica glass matrix, which fuses at a high temperature to produce a toothlike translucence.

As compared with metals, the atomic arrangements are complex. Because of the great strength of the bonds and the complexity of their structures, ceramic reactions are sluggish, if they exist. The dental porcelains are almost inert. During cooling, glass, for example, may be cooled very slowly, but the rate of atomic diffusion is so slow that it solidifies with a liquid structure instead of a crystalline structure. Although the internal energy of the super-cooled liquid or noncrystalline structure is greater than that of the crystalline arrangement, the former is apparently the stable form. Such a structure is called *vitreous* and the process of forming it is known as *vitrification*. In ceramic terms, vitrification is the development of a liquid phase, by reaction or melting, which, on cooling, provides the glassy phase.

High-fusing porcelain generally contains abut 75 to 85 per cent feldspar, 12 to 22 per cent quartz, and up to 4 per cent kaolin. The feldspar provides a glassy phase and serves as a matrix for the quartz, which remains in suspension after firing.

Quartz (SiO_2) is used in porcelain as a strengthener. At normal firing temperatures, it is structurally unchanged and serves to stabilize the mass at high temperatures.

Feldspars used in the manufacturing of dental porcelain are mixtures of potassium aluminum silicate, $K_2O \cdot Al_2O_3 \cdot 6SiO_2$, and albite, $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$. Natural feldspar is never pure, and the ratio of potash (K_2O) to soda (Na_2O) may vary. When feldspar is melted at approximately 1250 to 1500° C (2280 to 2730° F), it fuses to become a glass with a free crystalline phase.

The soda form of feldspar tends to lower the fusion temperature, while the potash form increases the viscosity of the molten material, causing less slump or pyroplastic flow of the porcelain to occur during firing. This is a desirable property because it prevents the rounding of margins, the loss of tooth form, and the obliteration of surface markings, which contribute to a lifelike appearance.

Kaolin is a hydrated aluminum silicate ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) that acts as a binder to increase the moldability of the unfired porcelain. Because of its opaqueness, it is present in only very small amounts, if at all.

In medium- and low-fusing porcelains the manufacturer mixes the components, fuses them, and then quenches the mass in water. Quenching results in internal stresses that produce considerable cracking and fracturing throughout the glass. This process is known as *fritting*, and the product is called a *frit*. The resultant brittle structure can be readily ground to a fine powder

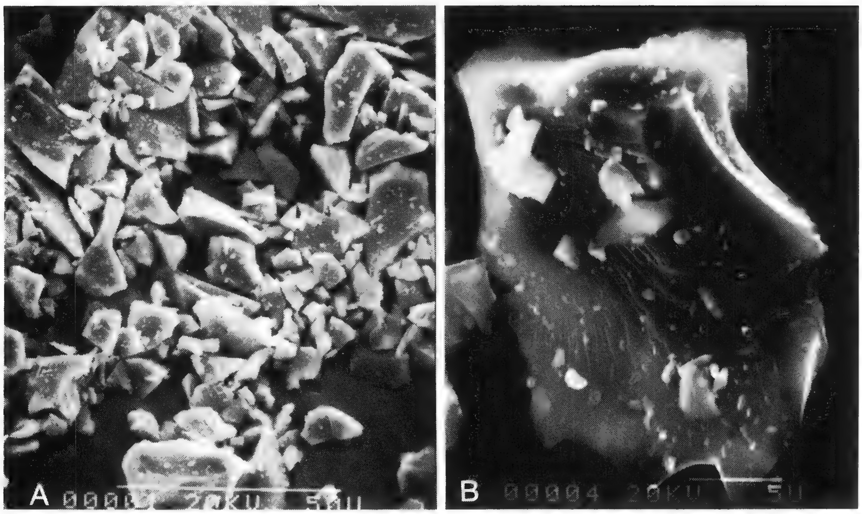


FIGURE 20–1

A, Electron micrograph of enamel porcelain powder. Magnification ×1000.
B, Electron micrograph of enamel porcelain powder. Magnification ×4000.

that is used to form the shape of a tooth (Fig. 20–1A, B).

During prefusing of the porcelain, a pyrochemical reaction between the ingredients has occurred, and much of the shrinkage associated with this reaction has taken place. During subsequent firing in the dental laboratory, the powders are fused together to form the restoration. The fusion temperature depends on the composition of the glass and must be carefully controlled to minimize pyroplastic flow. Compositions of typical glasses that have been employed in dental porcelain are given in Table 20–1.

The principal ion present in all glasses is oxygen, which forms very stable bonds with small multivalent atoms such as silicon, boron, germanium, or phosphorus. These structural units, such as the SiO_4 tetrahedrons or the BO_3 triangles, form the random network in glass. Thus, these elements are termed *glass formers*.

Dental porcelains use the basic silicon-oxygen network as the glass-forming matrix, but additional properties, such as low fusing temperature, high viscosity, and resistance to devitrification, are built in by the addition of other oxides to the glass-forming SiO_4 lattice. These oxides generally consist of potassium, sodium, calcium, aluminum, and boric oxides.

Potassium, sodium, and calcium oxides are used as *glass modifiers;* that is, they interrupt the integrity of the SiO_4 network and act as *fluxes*.

The alkalis (potash and soda) are introduced either as carbonates or as naturally occurring minerals (such as feldspar). In the latter case, some silica and alumina are added. Boron can be present as borax or boric acid. Lime, when used, can be added as calcium carbonate, which reverts to calcium oxide (CaO) during fritting.

The purpose of a flux is to lower the softening temperature of a glass by reducing the amount of cross-linking between the oxygen and the glass-forming elements. For example, sodium can supply an electron to an oxygen atom in the tetrahedron. Thus, the oxygen atom becomes part of only one tetrahedron instead of being shared with other tetrahedrons. In other words, the tetrahedrons become separated.

TABLE 20–1. CHEMICAL COMPOSITION OF SOME DENTAL PORCELAINS*

	High-Fire Porcelain		Medium-Fire Porcelain		Low-Fire Atmospheric		Low-Fire Vacuum			Metal-Bonded Porcelain A		Metal-Bonded Porcelain B
	D	*E*	*D*	*E*	*D*	*E*	*Aluminous Core*	*D*	*E*	*D*	*E*	*B*
SiO_2	72.9	65.1	63.1	64.3	68.1	67.6	35.0	66.5	64.7	59.2	63.5	66.2
Al_2O_3	15.9	19.4	19.8	19.1	8.8	9.7	53.8	13.5	13.9	18.5	18.9	14.5
CaO					3.5	3.7	1.12		1.78			1.4
Na_2O	1.68	2.4	2.0	2.4	4.7	4.5	2.8	4.2	4.8	4.8	5.0	6.1
K_2O	9.8	12.8	7.9	8.4	8.4	8.1	4.2	7.1	7.5	11.8	12.3	10.2
B_2O_3		0.15	6.8	5.2	6.4	6.3	3.2	6.6	7.3	4.6	0.12	
ZnO			0.25	0.25						0.58	0.11	
ZrO_2										0.39	0.13	
Firing temperature (°C)	1300	1300	1100	1100	960	960	980	980	950	900	900	940

*Chemical composition is given in percentages.
D = dentin; E = enamel.
From Yamada, H, and Grenoble, P: Dental Porcelain—The State of the Art. University of Southern California Conference Proceedings. 1977, p. 26; adapted from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 504.

Other metallic ions can also be introduced, as indicated in Table 20–1. The result is that the Si—O bonds become fewer, and the fused mass become less viscous; a lower maturing temperature also results. If too many tetrahedrons are disrupted, the glass may crystallize or *devitrify*.

By contrast, although boric oxide (B_2O_3) can act as a flux, it also forms its own glass network. Because the boric oxide forms a twin lattice with silica, it may still interrupt the more rigid silica network and cause a lowering of the softening point of the glass. Boric oxide also prevents thermal expansion increases, thereby allowing an increase in alkali content to lower the firing temperature even further.

The role of alumina (Al_2O_3) in glass formation is complicated. It cannot be considered a true glass former by itself because of the dimensions of the ion and the O:Al ratio. Nevertheless, it can take part in the glass network to alter the softening point and viscosity. Generally, Al_2O_3 is used in glass formation to increase the hardness and viscosity.

JACKET CROWN PORCELAIN

The porcelain jacket crown is an all-ceramic restoration that derives its strength from the introduction of additional alumina (Al_2O_3) into its composition. A high-strength core porcelain containing 40 to 50 per cent alumina crystals in a low-fusing glass matrix is formed first (Fig. 20–2). The glass selected for the matrix should have the same coefficient of thermal expansion as the alumina. The structure is seen in Figure 20–3. Dentin-colored porcelain of the usual glass type is then fired over the core along with a porcelain that simulates enamel (also of the glass type).

The alumina particles (Al_2O_3) are much stronger, with a higher modulus of elasticity, than the glass matrix. Consequently, greater energy is required for crack propagation to occur in the alumina-glass composite material, and greater strength is achieved. A 50 per cent by weight alumina-glass may have twice the strength of the glass phase alone.

FIGURE 20–2 Electron micrograph of aluminous core porcelain. Magnification ×4300.

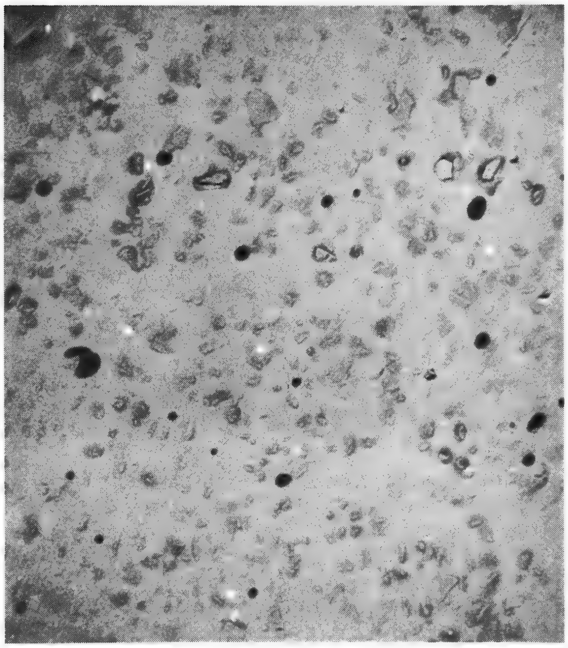


FIGURE 20–3 Photomicrograph of aluminous core porcelain illustrates alumina crystals (dark gray) surrounded by a matrix (light gray) of glass phase. Magnification ×200. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 506.)

A photomicrograph showing the propagation through an aluminous porcelain is presented in Figure 20–4. However, if the coefficients of thermal expansion of the two phases are different, the crack is propagated intergranularly and the strength is reduced (Fig. 20–5). The irregular path is the result of the stresses that exist around the alumina particles.

Even greater strength can be attained in the restoration by using a high-purity alumina, generally in excess of 97 per cent. However, the fusing temperature of the high-purity alumina is much higher than what can be attained with the usual dental laboratory equipment, and the material must be supplied in already fused preformed shapes. Also, the available thicknesses and resulting opacity limit the usage to nonvisible lingual surfaces. For anterior crowns, a thin curved sheet (0.6 mm thick) of high-purity alumina is inserted in the lingual aspect of the aluminous core to gain additional strength. The usual dentin and enamel porcelains are then fused as a veneer over the core.

METAL-CERAMIC PORCELAIN

The metal-ceramic crown is the most widely used restoration in dental ceramics. It consists of a metal casting onto which a veneer of porcelain is fused. A thin layer of opaque porcelain is fused over the casting to mask the metal, and porcelains designed to match dentin and enamel subsequently are fired over the opaque porcelain.

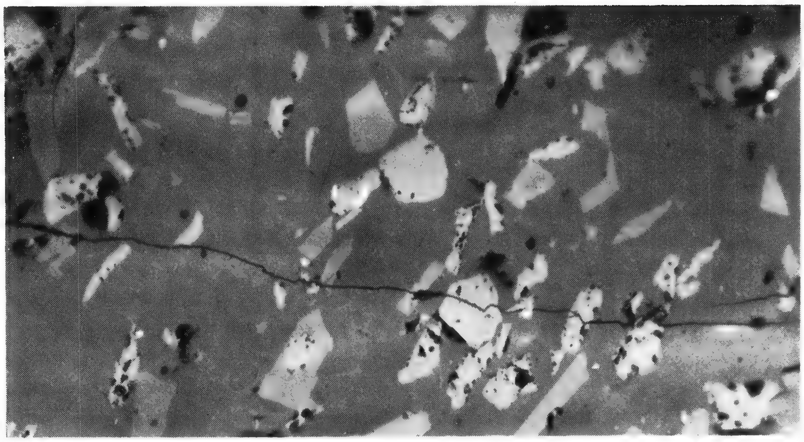


FIGURE 20–4 Photomicrograph of the fracture path in a two-phase system of dental porcelain reinforced with recrystallized alumina. (Courtesy of J. W. McLean.) (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 507.)

The composition of metal-ceramic porcelains generally corresponds to that of conventional glasses except for an increased alkali content. The addition of greater quantities of soda and potash is necessary to increase the thermal expansion to a level compatible with the metal casting and to lower the fusing temperature below that of the alloy.

The opaque porcelains contain relatively large amounts of metallic oxide opacifiers (such as zirconium, titanium, and tin) to mask the underlying metal and to minimize the thickness of the opaque layer.

It is important to note that the high-expansion porcelains used in metal-ceramics have an increased tendency to devitrify because of their alkali content. These porcelains should not be subjected to an excessive number of firings, since this increases the risk of producing cloudiness within the porcelain.

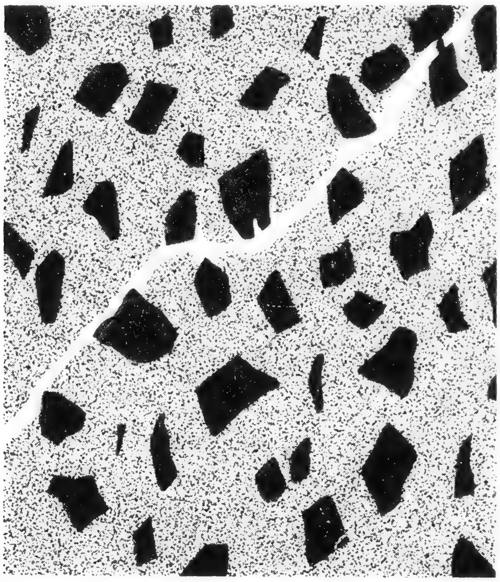


FIGURE 20–5 Diagram illustrating the fracture path in a two-phase alumina-glass system in which the coefficients of thermal expansion are different. (From McLean and Hughes, Br Dent J, Sept. 21, 1965; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 508.)

It is obvious that a proper meshing of the properties of the alloy and porcelain is imperative for success. Criteria and test methods for determining that compatibility have been suggested. They include measurements of the compatibility of coefficients of thermal expansion, thermal conductivity (to determine resistance to thermal shock), and the nature and strength of the metal-to-ceramic bond.

Special Types of Porcelains

The principal reason for choosing procelain as a restorative material is that high esthetic qualities can be attained in matching adjacent tooth structure in translucency and color. In order to accomplish this, various special types of porcelain are required.

Color frits are added to dental porcelain to obtain the various shades needed to simulate natural teeth. These coloring pigments are produced by fusing metallic oxides together with fine glass and feldspar and then regrinding them to a powder. These various powders are blended with the unpigmented powdered frit to provide the proper color. Examples of metallic oxides and their respective color renditions are: iron or nickel oxide, brown; copper oxide, green; titanium oxide, yellowish brown; manganese oxide, lavender; and cobalt oxide, blue.

Stains are supplied in kits and are made in the same way as the concentrated color frits. They are employed as surface colorants or to replicate enamel check lines, hypocalcification areas, or other tooth defects in the body of a porcelain restoration. Stains are often made from lower-fusing glasses so that they can be applied at temperatures below the maturing temperature of the restoration.

Overglazes or *applied glazes* are ceramic powders that are painted on the surface of a porcelain restoration. They are fired at a maturing temperature lower than that of the restoration to produce a transparent glossy layer on the surface.

The coefficient of thermal expansion of the overglaze should be slightly lower than that of the porcelain body to which it is applied. If the overglaze has a higher coefficient than the body, it cools under radial tension. The stresses that result may cause a crazing of the surface. Conversely, if the coefficient of the overglaze is

considerably lower than that of the body porcelain, compressive stresses may cause cracks in the glaze, which are known as "peeling."

In either case, an erosion of the overglaze may occur in the mouth, and the loss of the glaze exposes the rough and sometimes porous surface of the body porcelain. A smooth surface on the porcelain is essential to minimize plaque retention and provide a good soft tissue response. Also, the strength is reduced through the loss of surface glaze.

Mechanical Behavior

Because of its structure, glass is completely nonductile after vitrification. Dislocations and slip cannot occur. When it breaks, a brittle fracture occurs. Its compressive strength is high, and theoretically, its tensile strength is also high. The shear strength is low. However, in practice, the tensile strength of a ceramic is very low because surface defects such as minute cracks, porosities, and unevenness occur, as shown in Figure 20–6.

The cracks or surface irregularities may be extremely minute, as indicated in Figure 20–7. Surface irregularities may cause the cracks to deviate from a straight line, as shown in Figure 20–8. Such cracks result in the concentration of stresses. In metals, these stresses can be relieved by plastic deformation, but because glasses are nonductile, stress relief is not possible. If the structure is under tensile stress, the concentrated stress can easily exceed the strength of the ceramic body, and the depth of the crack increases. The deeper the crack, the greater is the concentration of stress, and a brittle fracture occurs rapidly. This theory may account for the almost explosive fracture of ceramic bodies that commonly occurs. On the other hand, under a compressive stress, the crack is not self-propagating, and the stress is resisted more successfully.

Cracks are believed to form during cooling of the ceramic after maturing. Regardless of the rate of cooling, the outside layer or "skin" cools more rapidly than the interior. Consequently, the "skin" is under compression, and the interior contains tensile stresses because its thermal contraction may be partially prevented by the rigid skin that has already solidified. This differential dimensional change may possibly fracture or rupture the "skin" and produce minute cracks when the opposing stresses try to neutralize each other in this region.

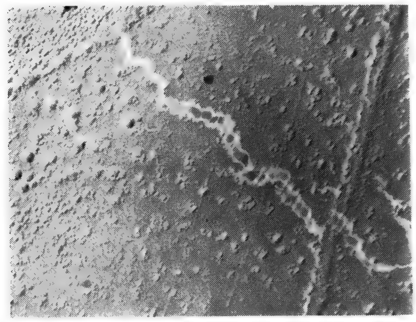


FIGURE 20–7 Electron micrograph of a microcrack in dental porcelain, 0.1 μm wide. Magnification ×10,000. (Courtesy of J. W. McLean. Crown copyright reserved; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 510.)

A significant clinical factor in the weakening of glass surfaces is the effect of moisture contamination. Water plays a vital part in the stress rupture of glass and produces a time-dependent reduction in strength. The process has been described as a replacement of the alkali ions in glass by hydrogen ions, which attract water molecules into the spaces originally occupied by the alkali.

Thus water (saliva) could act as a type of network modifier in weakening the glass. Undamaged glass is weakened by wet storage and shows delayed fracture when it is stressed at constant load under wet conditions. It is highly probable that surface weakening of dental porcelain may also occur in the mouth. Also, loads in the occlusal surfaces that would not normally fracture the material might overstress the flaw system once stress rupture is initiated.

Handling Porcelain

Condensation

The porcelain used to construct the jacket crown or metal-ceramic crown must be shaped to proper tooth

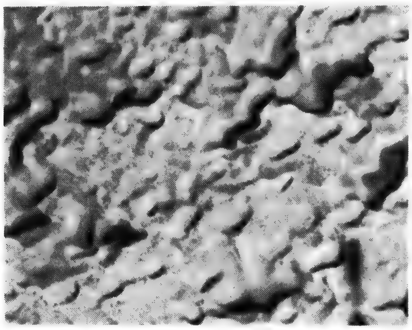


FIGURE 20–6 Electron micrograph of a surface of a dental porcelain showing flaws and discontinuities. Magnification ×30,000. (Courtesy of J. W. McLean and T. H. Hughes, Warren Spring Laboratory, England. Crown copyright reserved; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 510.)

FIGURE 20–8 Electron micrograph of a microcrack showing change in direction as a result of a surface fault. Magnification ×5000. (Courtesy of J. W. McLean and T. H. Hughes. Crown copyright reserved; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 510.)

TABLE 20–2. INFLUENCE OF CONDENSATION METHOD ON THE PHYSICAL PROPERTIES OF DENTAL PORCELAIN

Method of Condensation	Firing Shrinkage, Volumetric *(per cent)*	Apparent Specific Gravity	Modulus of Rupture *MPa*	Modulus of Rupture *psi*
Vibration	38.1	2.35	48.3	7000
Spatulation	38.4	2.34	49.6	7200
Brush application	40.5	2.36	36.5	5300
No condensation	41.5	2.36	33.8	4900

From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 516.

form before it is fired. It is mandatory that the procelain particles be packed together as closely as possible in order to minimize the amount of porosity and the shrinkage occurring during the firing process. This packing, or *condensation,* may be achieved by various methods, including vibration, spatulation, and the dry brush technique (Table 20–2).

The first method utilizes mild vibration to densely pack the wet powder on the underlying framework. The excess water is blotted away with a clean tissue. In the second method, a small spatula is used to apply and smooth the wet porcelain. The smoothing action brings the excess water to the surface, from which it is removed. The third method utilizes the addition of dry porcelain powder to the surface to absorb the water. The dry powder is placed by a brush to the side opposite an increment of wet porcelain. As the water is drawn toward the dry powder, the wet particles are pulled together. Whichever method is used, it is important to remember that the surface tension of the liquid is the driving force in condensation and that the porcelain must never be allowed to dry out.

Firing Procedure

The thermochemical reactions between the ingredients are virtually completed in most cases during the original fritting process. Therefore, the purpose of firing is simply to fuse the particles of powder together properly in a process called *sintering.*

After the condensation is completed, the porcelain restoration is placed on a fire-clay slab or tray and placed in front of the open muffle of a preheated furnace (approximately 650° C [1200° F]). This permits the remaining water vapor to dissipate. Placement of the condensed mass directly into even a moderately warm furnace results in a rapid production of steam, which introduces voids or fractures large sections of the veneer. After preheating, the mass is placed in the furnace, and the firing cycle is initiated.

The porcelain should never be allowed to contact the muffle walls or floor. At high temperatures, the porcelain melts, and some of the ingredients may fuse to the heating element. Such a contamination renders the heating element extremely brittle, and it may fracture during cooling or subsequent heating. This precaution is particularly important when a platinum-wound muffle is used.

The size of the powder particles influences the apparent density of fired porcelain. The progressive changes that occur during the firing of porcelain powders of coarse and fine particle sizes, respectively, are shown in Figure 20–9. The upper row of photomicrographs represents the structure of a porcelain during firing at the temperatures indicated with particles greater than 125 μm in diameter, and the lower row the same shows vitrification changes for particles 44 μm or less in diameter.

Regardless of the particle size, the white areas at 1177° C (2150° F) are the powder particles. The areas between are the voids. At this temperature, the voids are occupied by the atmosphere of the furnace. As fusion begins, the particles unite at the points of contact (2200° F, Fig. 20–9). As the temperature is raised, the fused glass gradually flows to fill up the air spaces, but air becomes trapped in the form of bubbles because the fused mass is too viscous to allow all of it to escape.

Shrinkage

Even well-condensed porcelain shrinks when it is fired. The cause of this shrinkage is loss of water and densification through sintering.

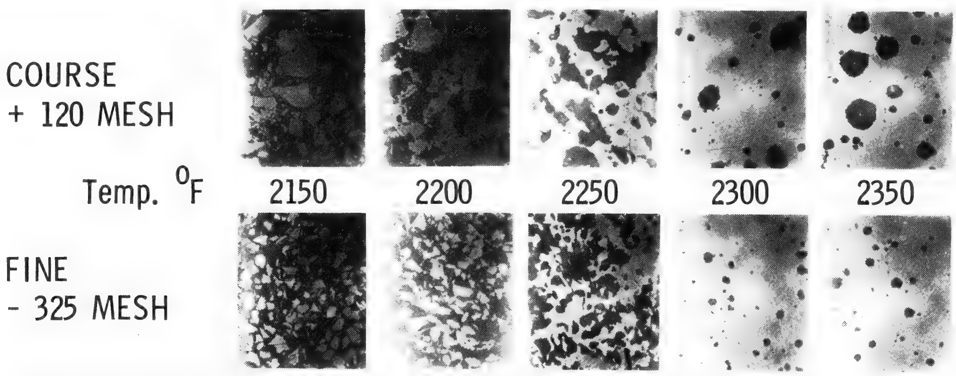


FIGURE 20–9 Progressive vitrification of coarse- and fine-grained porcelain. Top row: diameter of powder particles is greater than 125 μm. Bottom row: diameter of particles is less than 44 μm. Cross section of porcelain teeth fired on a 15-minute cycle to the temperature indicated. Original magnification ×200. (From Vines and Semmelman, J Dent Res, Dec. 1957; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 514.)

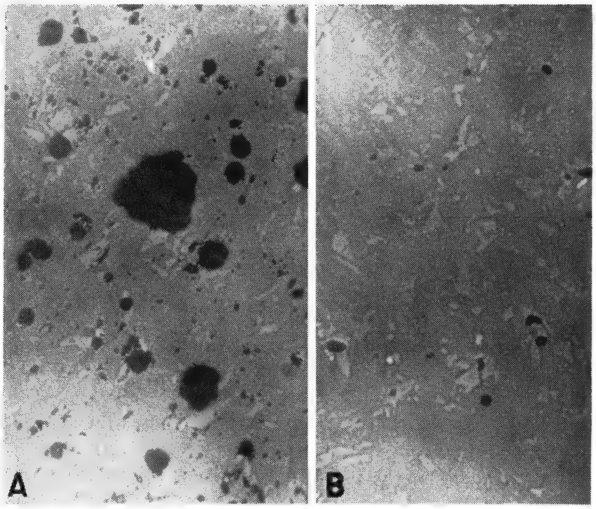


FIGURE 20–10

A, Air-fired porcelain.
B, Vacuum-fired porcelain. The cored structure is crystalline quartz.
(From Vines and Semmelman, J Dent Res, Dec. 1957; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 517.)

The immediate cause for the shrinkage is the contraction of the body as the powder particles melt and fuse together, as indicated in Figure 20–9. A surface tension action by the fused mass draws any unfused portions toward the center and into the voids or interstices. The final structures may be cored with the quartz crystalline phase, with the glass phase forming the matrix (Fig. 20–10).

The effect of the firing temperature on the shrinkage is demonstrated in Table 20–3. Small specimens of a medium-temperature–maturing porcelain were fired to the temperatures indicated in 15 minutes and held at those temperatures for 30 minutes before cooling. As can be noted, the volume shrinkage did not change to any extent after the firing temperature (1175° C) was attained.

Porosity

Bubbles or voids in the fired porcelain are caused by the inclusion of air during fusion, although there is evidence that in the case of some of the high-fusing porcelains they may appear also as a by-product of the vitrification of the feldspar.

As might be expected, bubbles reduce the translucence and strength of dental porcelain. As can be noted from Figure 20–9, the bubbles formed with the larger-size porcelain powders, although larger, are not as numerous as are the smaller bubbles formed with the smaller-size particles. Because of the difference in indices of refraction between the porcelain body and the entrapped gas, the porcelain with larger particle sizes but fewer bubbles is more translucent than that fired with smaller particle sizes. When the bubbles are fewer or are eliminated, the finer size porcelain produces the more translucent body.

These bubbles or blebs seldom appear on the surface of a ceramic tooth or crown because the entrapped gases near the surface can be released. Also, gas bubbles are not as numerous in high-temperature–maturing porcelains as in low-temperature–maturing ones. The viscosity of the glass phase in the former porcelains is sufficiently low to allow some escape of the air during vitrification.

Three methods for the reduction or elimination of bubbles or voids have been suggested:

1. The porcelain can be fired in a partial vacuum so the air is removed before it is entrapped by fusion. Vacuum firing is by far the most common method used for producing dental restorations.
2. A diffusible gas is substituted for the ordinary furnace atmosphere. The air is then driven out of the interstices during the firing, and the diffusible gas is substituted. During fusion, such entrapped gases diffuse outward through the porcelain or are dissolved in the porcelain.
3. If the fused porcelain is cooled under pressure, the air bubbles can be compressed in size so that their effect is negligible.

The reduction in number and size of the air voids by vacuum firing is shown in Figure 20–10. Not all of the air can be evacuated from the furnace. Therefore, a few bubbles are present in B but they are in contrast to the bubbles obtained with the usual air-firing method shown in A.

The diffusible gases that can be introduced into the furnace during vitrification are helium, hydrogen, and steam. As previously noted, when these gases are trapped in the voids, they diffuse into the porcelain body. The structure of the final product resembles that of the vacuum-fired porcelain shown in Figure 20–10B.

When porcelain is self-glazed by reheating, the diffusible gas method is somewhat superior to the others because further gas diffusion takes place and the bubbles virtually disappear. When the vacuum-fired porcelain is reheated, the bubbles are unchanged.

If porcelain is fired in air, the bubbles can be reduced by increasing the air pressure to 10 atmospheres, for example. The bubbles are reduced to a size comparable to that obtained with the other two methods. The pressure is, of course, maintained until the porcelain has cooled to rigidity. The pressure method offers a disadvantage in that the porcelain cannot be refired or glazed at atmospheric pressure without the bubbles being restored to their original size by the compressed gas.

Glazing

The surface of the crown should be completely smooth when it is placed in the mouth. Otherwise food debris may cling to it.

TABLE 20–3. EFFECT OF THE FIRING TEMPERATURE ON THE PHYSICAL PROPERTIES OF A DENTAL PORCELAIN

Temperature		Firing Shrinkage by Volume	Apparent Specific	Modulus of Rupture	
(°C)	(°F)	(per cent)	Gravity	MPa	psi
1040	1900	16.0	1.73	12.9	1870
1100	2000	—	2.14	33.1	4800
1150	2100	27.7	2.35	55.2	8000
1175	2150	35.4	2.37	65.9	9560
1200	2200	34.5	2.33	58.1	8430

From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 516.

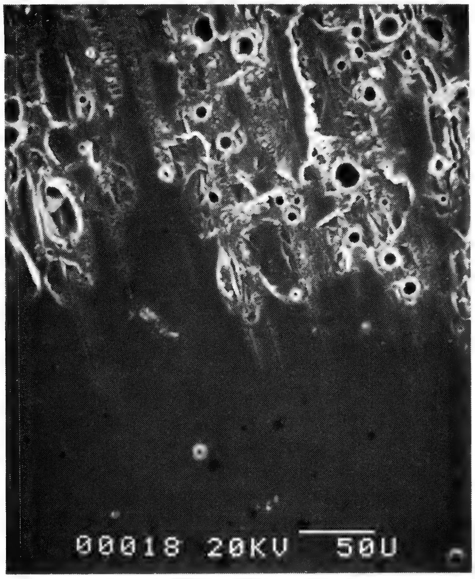


FIGURE 20–11 Electron micrograph of glazed porcelain in which a portion of the glaze (top of picture) was subsequently removed, revealing the underlying porosity. Magnification ×310.

There are always sufficient blebs and porosities present to prevent a smooth polished surface from being obtained, and such surface defects are best masked by a surface glaze.

An overglaze can be applied to the surface as previously described, or the body itself can be glazed by a separate firing (autoglazing). If the previously fired porcelain is heated to its fusion temperature and held at that temperature for 1 to 3 minutes before it is cooled, the glass flows and a smooth glazed surface is developed (Fig. 20–11).

Physical Properties

The strength of a porcelain restoration is probably its most important mechanical property. As previously noted, the compressive strength of ceramic bodies is greater than either their tensile or their shear strength.

The strength of porcelain is greatly dependent on its composition, surface integrity, and internal structure. The presence of voids and blebs can affect its strength, as illustrated in Figure 20–12. The load required to fracture the crown with the lesser porosity was almost twice that at which the more porous crown broke. The firing temperature is also important (Table 20–3). Unless the vitrification is complete, the structure is weak. Also, if the ceramic is overfired, the strength decreases because more of the quartz core is dissolved in the glass matrix and the core network is weakened. However, this effect is more deleterious to the esthetic qualities. Overfiring causes the material to become more transparent and to appear "glassy." Too rapid cooling increases the surface cracks and weakens the procelain. Glazed porcelain is much stronger than the unglazed variety, with the glaze being effective in reducing surface crack density and propagation. If the glaze is removed by grinding, the transverse strength may be only half that with the glaze present (Table 20–4). This observation is of clinical importance. After the porcelain restoration is cemented in the mouth, it is common practice for the dentist for make a final adjustment of the occlusion by grinding the surface of the porcelain.

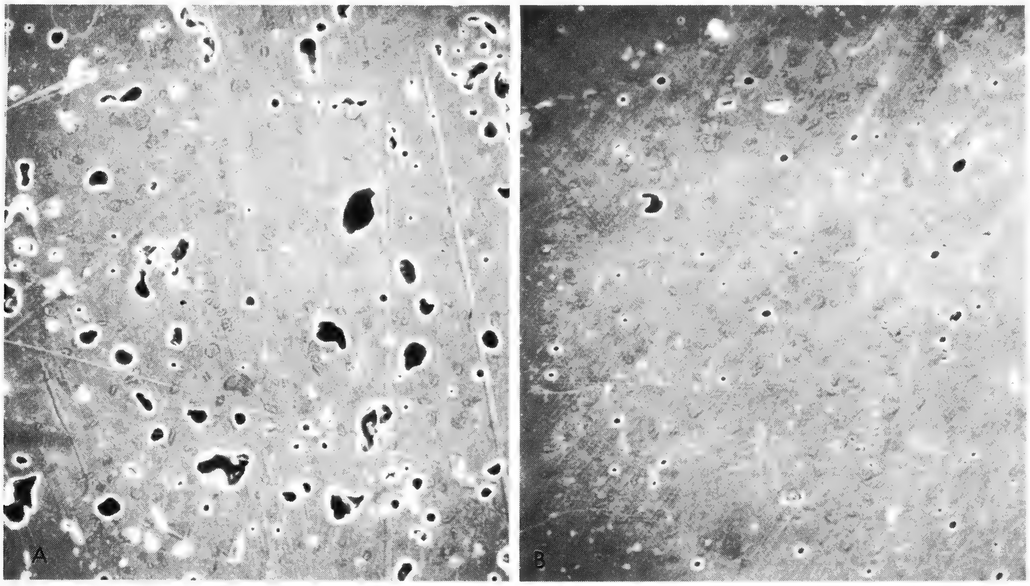


FIGURE 20–12

A, Porosity in the core porcelain of a jacket crown that failed under an incisal load of 94 kg.
B, Porosity in the core porcelain of a jacket crown that failed under an incisal load of 160 kg. Magnification ×200. (From Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 518.)

Unfortunately, removing the surface glaze weakens the porcelain markedly.

Vacuum firing has little effect on the transverse strength of porcelain (Table 20–4). The reason is probably that surface crack formation is not related to the atmosphere during firing. Apparently, so far as transverse strength is concerned, this factor is of greater importance than is the weakening effects of the voids.

It is interesting to note that the modulus of rupture of aluminous porcelain is the same whether it is glazed or unglazed (Table 20–4). Apparently, the strengthening effect of the alumina is sufficient to counteract to some extent the weakening effect of surface discontinuities. The strengthening effect of using a preformed high-purity fused alumina insert in a jacket crown may be considerable, as indicated by its modulus of rupture (Table 20–4). However, there must be good contact and a bond with the surrounding porcelain.

The method of firing also affects the strength (Table 20–3). A firing schedule that employs a lower temperature and a longer time is superior, so far as strength is concerned, to a shorter firing period at a higher temperature. Also, sharp edges and angles are better preserved at the lower firing temperatures.

Evidently, sufficient time at the proper temperature should be allotted for the viscous melt to flow completely through the unmelted parts and weld them together. As the temperature rises, the viscosity of the molten phase decreases and it flows more easily, but perhaps too much of the material is fused at the higher temperature, with the result that the strength is decreased. As with similar materials, an optimal ratio between the matrix and the core should be maintained for maximal strength.

METAL-CERAMIC ALLOYS

The first metal-ceramic alloys developed were composed largely of gold, platinum, and palladium. As the price of gold significantly increased in the 1970s, alternative alloys were developed.

There are four major classifications (Table 20–5) of metal-ceramic alloy alternatives based on the principal elements present: (1) gold-platinum-palladium alloys, (2) gold-palladium alloys, (3) high–palladium-content alloys, and (4) base metal alloys. Table 20–6 shows representative compositions for the four types of alloys, and Table 20–7 shows representative physical properties. Slight variations occur between different manufacturers.

TABLE 20–4. MODULUS OF RUPTURE OF VARIOUS DENTAL PORCELAINS*

Classification	Firing Atmosphere	Surface Condition	Modulus of Rupture *MPa*	Modulus of Rupture *psi*
Porcelain†	Air	Ground	75.8	11,000
		Glazed	141.1	20,465
	Vacuum	Ground	79.6	11,547
		Glazed	132.3	19,187
Aluminous porcelain	Air	Ground	135.9	19,709
		Glazed	138.9	20,142
Fused alumina			519.3	75,310

*Adapted from McLean and Hughes, Br Dent J, Sept. 21, 1965; from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 519.

†A dental porcelain. Both porcelains are the medium-temperature maturing variety and fused in air.

TABLE 20–5. METAL-CERAMIC ALLOY ALTERNATIVES

Gold-platinum-palladium	99 per cent noble metals
Gold-palladium	
Containing silver	80 per cent noble metals
No silver	90 per cent noble metals
High–palladium-content	
Containing silver	60 per cent noble metals
No silver	80 per cent noble metals
Base metal	
Nickel-based	No noble metals
Cobalt-based	No noble metals

Gold-Platinum-Palladium Alloys

The gold-platinum-palladium alloys were developed in the 1950s and contain primarily gold (approximately 80 to 88 per cent). Platinum and palladium combine to account for about 10 per cent of the composition, with the remainder of the composition formed of elements present in amounts of 1 per cent or less (Table 20–6).

These alloys have the longest record of successful clinical use and have excellent castability and fit (Fig. 20–13). A good porcelain-to-metal bond is achieved, and in bond strength determinations, failure usually occurs within the porcelain, which indicates that the bond is stronger than the porcelain.

The melting range of these alloys is the lowest, so that porcelain fusion temperatures are closer to the melting range of the metal. This temperature proximity produces greater high-temperature distortion or "sag" than occurs with the other alloys, and successful use requires proper casting design. These alloys have the lowest strength, stiffness, ductility, and hardness (Table 20–7).

Long-span prostheses can be successfully fabricated in this type of alloy but should be designed with a facial veneer of porcelain and the remainder of the restoration formed in metal. The authors have observed successful prostheses utilizing this design over the past 25 years. Full porcelain coverage frameworks longer than three units should be cast in other metal-ceramic alloys with superior physical properties, since there is less metal thickness with this casting design.

Gold-platinum-palladium alloys have the highest cost per unit weight and the highest density (Table 20–7), which results in the highest metal cost per cast unit.

Gold-Palladium Alloys

There are two types of gold-palladium alloys: those containing silver and those without silver. The silver-containing alloys have a gold composition of around 50 to 55 per cent, approximately 25 per cent palladium, and 15 per cent silver. The alloys that do not contain silver have about the same amount of gold with an

TABLE 20–6. METAL-CERAMIC ALLOY ALTERNATIVES BY PER CENT COMPOSITION

Alloy	Au	Pt	Pd	Ag	Cu, Ga	Co	Ni	Cr
Gold-platinum-palladium	87.5	4.5	6.0	1.0				
Gold-palladium								
Containing silver	52.5		27.0	16.0				
No silver	51.5		38.5					
High–palladium-content								
Containing silver			60.0	28.0				
No silver	0–2.0		80.0		0–10	0–5		
Base metal								
Nickel-based							60–80	12–22
Cobalt-based						50–60		25–30

increase in the palladium content (Table 20–6). Both types of alloys are significantly lower in cost than gold-platinum-palladium alloys, since there is less gold and larger amounts of palladium.

Gold-palladium alloys exhibit excellent castability and fit, have a good porcelain-to-metal bond, and have significantly improved physical properties compared with gold-platinum-palladium alloys (Table 20–7). They have less high-temperature distortion and higher strength and hardness. They can be sucessfully used in long-span full porcelain coverage restorations.

The silver-containing alloys in this group were developed first but occasionally caused porcelain discoloration, which stimulated the development of nonsilver gold-palladium alloys.

High–Palladium-Content Alloys

Two different types of high–palladium-content alloys are also available based on the presence or absence of silver. The silver-containing alloys (commonly called palladium-silver alloys) typically possess about 60 per cent palladium and 30 per cent silver. The nonsilver variety contain about 80 per cent palladium with considerable variation in the remaining components, depending on the manufacturer. Copper, cobalt, and gallium have been used (Table 20–6).

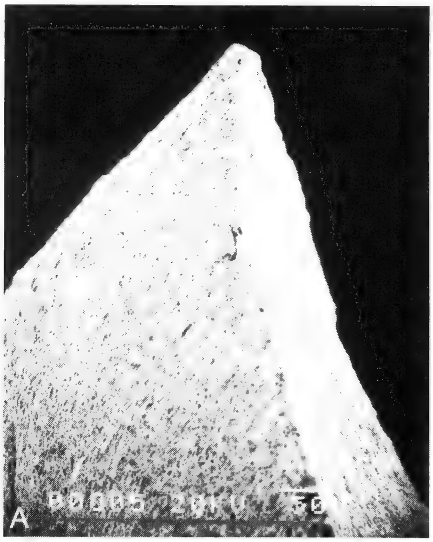
These alloys also show good castability and fit (Fig. 20–14A, B), although uniquely different handling characteristics are manifested between different brands (Fig. 20–14C, D). These alloys are significantly lower in cost than the gold-palladium alloys and possess roughly similar physical properties (Table 20–7).

Porcelain discoloration is a problem with the silver-containing alloys, and additional processing procedures are required to avoid significant color changes. Some individuals believe that a certain amount of discoloration is unavoidable, owing to the silver, and subsequently that use should be limited to clinical situations in which darker shades of porcelain are required or to posterior applications. Discoloration is not a problem with nonsilver high–palladium-content alloys.

Some of these alloys may be sensitive to phosphate-bonded investments containing carbon and require the use of a carbon-free investment.

Base Metal Alloys

Owing to the requirements of metal-ceramic compatibility, the majority of the base metal–ceramic alloys are composed primarily of nickel and chromium. The nickel content may range from 60 to 80 per cent, while the chromium content may vary between 12 and 22 per cent (Table 20–6). The chromium is essential to provide



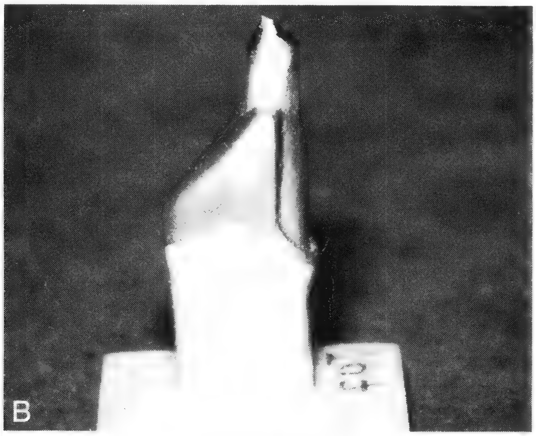


FIGURE 20–13

A, Electron micrograph of gold-platinum-palladium alloy margin. Magnification × 200.
B, Gold-platinum-palladium alloy framework in the as-cast state seated on its die.

TABLE 20–7. PHYSICAL PROPERTIES OF METAL-CERAMIC ALLOYS

	Au-Pt-Pd	Au-Pd-Ag	Au-Pd, no Ag	High Pd with Ag	High Pd, no Ag	Base metal
Density	18.3	13.8	13.5	10.3	11.5	8.5
Casting temperature (° C)	1260	1320	1350	1375	1275	1385
Hardness (after firing of porcelain)	180	220	220	190	240	240
Yield strength (kg/cm²)	4500	5600	5800	4700	4500	5200

passivation and corrosion resistance. Other alloy formulations include chromium-cobalt and iron-chromium.

The high melting temperature of these alloys requires use of high-temperature heat sources, but more important is the compensation for casting shrinkage required at these elevated temperatures to obtain a clinically acceptable fit. In the early years of using base metals, many castings were made with unacceptable fits. With the development of materials and techniques specifically designed for these alloys, experienced individuals can obtain well-fitting castings with sharp margins (Fig. 20–15A, B).

An examination of the mechanical properties of base metal alloys and gold alloys shows that in general the base metal alloys have a modulus of elasticity approximately 1.5 to 2 times that of conventional gold alloys. Since elastic modulus is a measure of the stiffness or rigidity of materials, this property would enhance the application of base metal alloys for long-span bridges in which flexure can cause failure. Given an equal thickness of noble metal alloy and base metal alloy, the base metal alloy bridge would flex slightly less than the noble alloy material under the same occlusal forces.

The majority of these alloys are considerably harder

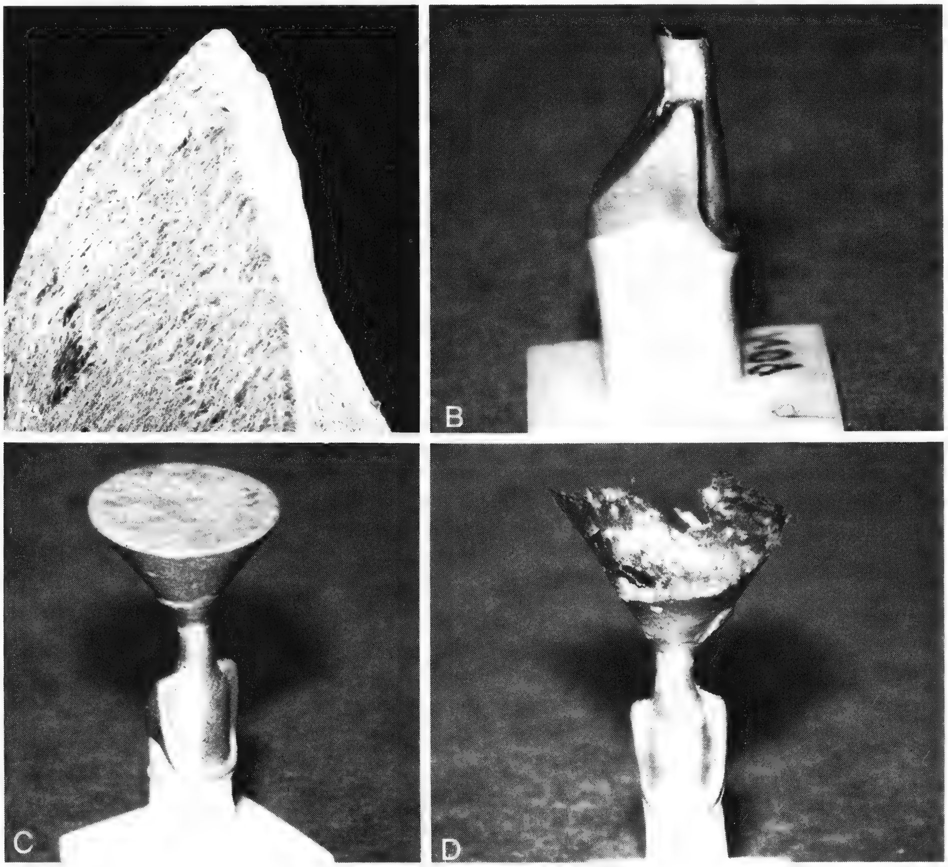


FIGURE 20–14

A, Electron micrograph of nonsilver high–palladium-content alloy margin. Magnification ×200.
B, Nonsilver high–palladium-content alloy framework in the as-cast state seated on its die.
C, A brand of nonsilver high–palladium-content alloy that melted and cast like traditional gold-containing alloy. Note the form of the button.
D, A brand of nonsilver high–palladium-content alloy that melted and cast like a base metal alloy.

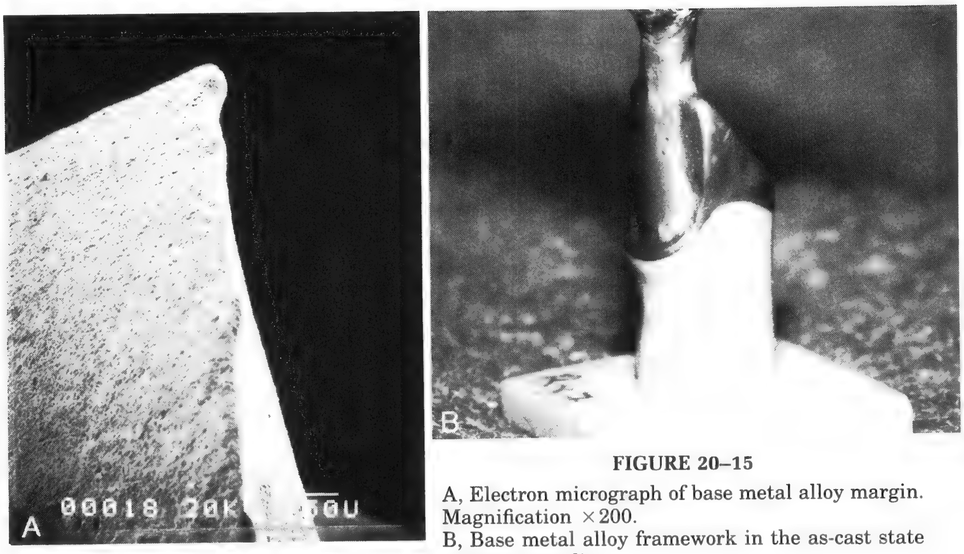


FIGURE 20–15

A, Electron micrograph of base metal alloy margin. Magnification ×200.
B, Base metal alloy framework in the as-cast state seated on its die.

than the noble metal alloys (Table 20–7). Because of this relatively high hardness, cutting of sprues and grinding and polishing of the prosthesis require the use of high-speed equipment. Clinically, it is unlikely for significant occlusal wear of the alloy to occur. Therefore, particular attention must be directed toward perfecting occlusal equilibration. The removal of defective clinical units is also more difficult than with noble metal alloys, since the greater hardness causes difficulty in cutting and rapidly wears the carbide burs and diamond points.

In addition to the obvious economic considerations, the lower density of base metal alloys may be a factor in producing adequate dental castings. Since most dental castings are made in centrifugal casting machines, the lower density may play a role in the difficulty reported by some investigators in attaining precision with castings with certain of these alloys. However, with improvements in techniques, an experienced technician can obtain quality castings.

The question of metal-ceramic compatibility is basic to the selection of an alloy system for this type of restoration. Two requirements are implicit. The metal must not interact with the ceramic in such a way as to visibly discolor the porcelain at the interface or marginal regions. Moreover, the metal-ceramic system must form a stable bond at the interface that can withstand normal stresses in the mouth.

Evaluation of the metal-ceramic bond, which is discussed in greater length later in this chapter, is complicated by the lack of an accepted laboratory test with proven clinical significance. Different bond strength tests have resulted in widely varying results in regard to the strength of base metal-ceramic bonds. Some tests indicate that the strength of such bonds equals or exceeds that of the high noble metal alloys, while other tests indicate the reverse. However, the tests generally have shown that bond failure occurs through the oxide layer rather than through the porcelain, as occurs with noble metal alloys (Fig. 20–16A, B).

The bond strength tests also make it clear that different base metal alloys vary widely in their abilities to bond to porcelain. These differences are related to the minor constituents of the alloy. It is also clear that certain base metal–ceramic combinations are incompatible. The American Dental Association acceptance program for metal-ceramic alloys suggests certain screening tests for such compatiblity. The base metal alloys are much more "technique-sensitive" than their high noble metal alloy conterparts. Fortunately, from a practical point of view, these considerations are primarily a

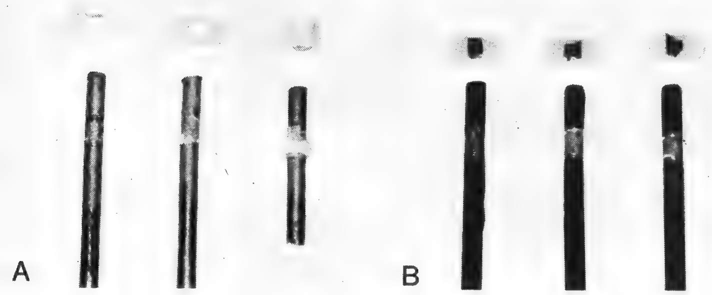


FIGURE 20–16

A, Bond strength test specimens in which porcelain was baked around the alloy rod in the form of a doughnut. Noble metal alloy specimens show porcelain that still adhered to metal rods.
B, Base metal alloy specimens show failure through the oxide layer. Note that little porcelain remains on rods, and fractured porcelain segments are coated with dark oxide.

concern for the dental laboratory and the technicians who fabricate prosthetic devices from these alloys.

On the basis of recent surveys, the use of base metal alloys by dental laboratories is rapidly increasing, at the expense of the traditional high noble metal–ceramic alloys. Laboratory personnel indicate a very high degree of satisfaction with the handling properties of base metal-ceramic alloys such as casting, finishing, and porcelain bonding. Unfortunately, at present long-term data from a wide range of practitioners are not available concerning the clinical performance of restorations fabricated from these alloys.

Biocompatibility

Certain base-metal alloys contain beryllium. This element is added to the alloy to reduce the fusion temperature, improve the casting characteristics, refine the grain structure, and possibily participate in the bonding of porcelain. It is widely recognized that beryllium is potentially toxic under uncontrolled conditions. Inhalation of the dusts and fumes of beryllium and its compounds is the main route of exposure. The diagnosis of chronic beryllium disease is difficult and requires the establishment of beryllium exposure.

To date, there have been no documented cases of beryllium toxicity of dental origin. However, it has been shown that under certain working conditions, notably the absence of adequate local exhaust ventilation, beryllium in base metal alloys can present a dental occupational health problem. Therefore, in laboratory and clinical situations in which grinding of beryllium-containing alloys is performed, adequate local exhaust ventilation safeguards should be employed.

In certain nondental industrial applications and environmental conditions, nickel and its compounds have been implicated as potential carcinogens and as sensitizing agents. Since the nickel content of base metal alloys can exceed 80 per cent, precautions should be employed during the use of these alloys.

There is no experimental evidence that nickel compounds are carcinogenic when they are used in the oral cavity. However, there is strong epidemiologic evidence that occupational exposure of workers to certain nickel compounds is associated with increased incidence of specific types of cancer. The prudent course of action requires that precautions be taken to prevent the aspiration of nickel-containing dust produced during dental grinding operations.

In addition to its carcinogenic potential, nickel is also recognized as a potent sensitizing agent. On the basis of the available evidence, the potential risks that might be anticipated with intraoral exposure to nickel-containing alloys contraindicate their use in nickel-sensitive patients.

THE METAL-CERAMIC BOND

The nature of the bond between noble metal alloys and dental porcelain has been the subject of considerable discussion. As noted, this is appropriate, since the success of a metal-ceramic crown depends on a strong bond between the metal and the ceramic veneer. Earlier workers considered that "wetting bonds" in one instance, and van der Waal's forces in the other, could adequately explain the observed strengths of metal-ceramic bonds. However, current research in this field tends to disregard the part played by van der Waal's forces, since such forces are small and can be subject to misinterpretation.

The nature of the metal-ceramic bond has become better defined and probably can be divided into three main components: mechanical, chemical, and compressive.

Mechanical Bonding

When the metal casting is prepared to accept porcelain, some surface grinding is usually performed, which may be followed by the use of an air abrasive. In both situations, considerable surface irregularities are present (Fig. 20–17A, B). Microscopic examination of the metal-ceramic interface indicates that porcelain flows

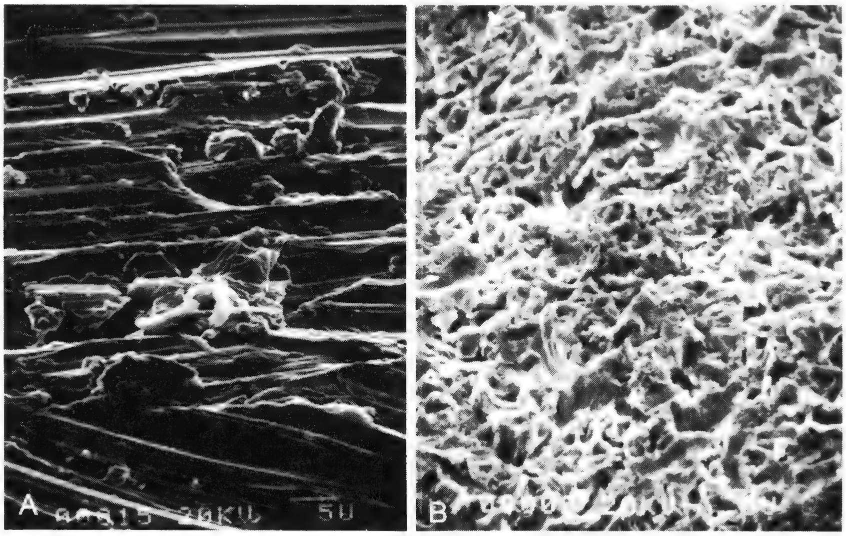


FIGURE 20–17
A, Electron micrograph of a casting that was ground with an abrasive stone. Magnification ×1800.
B, Electron micrograph of a casting that was air-abraded with 50-μ aluminous oxide. Magnification ×1800.

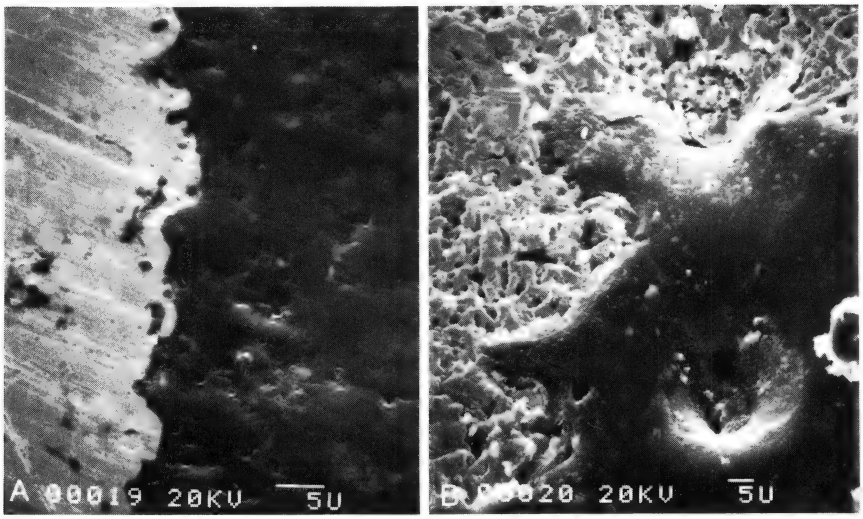


FIGURE 20–18

A, Electron micrograph of cross-sectional specimen through porcelain-alloy interface. Magnification ×2000.

B, Electron micrograph of porcelain (lower left) after being fused to oxidized alloy surface (upper left). Note that porcelain flows into and around surface projections on the alloy surface. Magnification ×1000.

into these irregularities. It is therefore reasonable to conclude that some form of *mechanical interlocking* has taken place (Fig. 20–18A, B). Such a mechanical "bond" must contribute something to the resistance of the porcelain to shear stresses.

Chemical Bonding

The precise nature of any chemical bond of the porcelain to the metal substrate depends on the composition of the alloy. This discussion concerns the bond to traditional noble metal alloys, and it must be appreciated that the bonding mechanism of other alloy systems, such as high–palladium-content and base metal alloys, may be somewhat different.

There is strong evidence for some form of chemical bonding. Electron microprobe examination of the metal-ceramic interface indicates that indium or tin migrates to a noble metal alloy surface to form indium or tin oxide, which combines with the porcelain during firing.

Further evidence of chemical bonding is that cleansing of the metal with hydrofluoric acid reduces the bond strength. This indicates that the oxide film does contribute to the bonding mechanism. When dental porcelain is fired onto a metal with a definite oxide layer, the oxygen surface of the molten glass (porcelain) diffuses with the oxygen surface on the metal to reduce the number of bridging oxygens and thus improves the screening of the cations at the interface. If the glass is not saturated with the particular oxide, it dissolves the oxygen with its metallic cations. The glass at the glass-oxide interface then becomes saturated with oxide. This glass remains constant in composition (at constant temperature) and is in thermodynamic equilibrium with the oxide, resulting in a balance of bond energies and a chemical bond.

The critical requirement of maintaining saturation at the oxygen-glass interface is that the rate of solution of the oxide at the interface is higher than the rate of diffusion of the dissolved oxide away from the interface.

The first requisite for a strong adhesive bond is that the adhesive must wet the adherent. In the present case, the ceramic material is treated as the adhesive because it flows onto the alloy during firing. The wettability of the adhesive can be measured by its contact angle. Obviously, the contact angle of the ceramic material is determined while it is a liquid above the fusion temperature, but its adhesion can be measured at room temperature because the same thermodynamic conditions of stress persist after solidification.

The contact angles of various commercial porcelains for dental use are given in Table 20–8. Special casting alloys that have been matched with each porcelain are supplied. The less the contact angle, the better is the wetting ability. Any contact angle greater than 90 degrees indicates a lack of wetting and, of course, adhesion. Apparently, material D does not adhere to any of

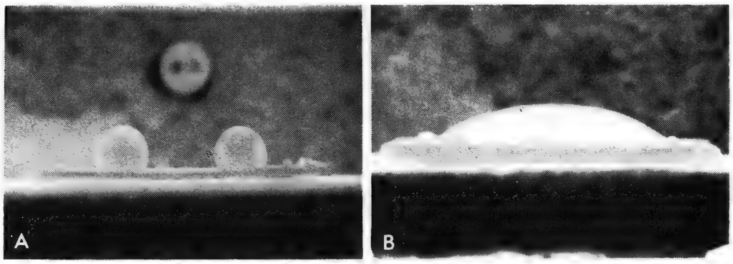
TABLE 20–8. CONTACT ANGLES (DEGREES) FOR ENAMELS ON VARIOUS METALS USED IN DENTAL RESTORATION*

Enamel	Without Bonding Agent	With Bonding Agent	On Platinum†	On Palladium†	Temperature °C	Temperature °F
A	40	50	54	52	1040	1900
B	53	39	64	60	1040	1900
C	59	70	97	95	1040	1900
D	102	92	102	108	1150	2100
E	52	28	48	46	1040	1900

*Adapted from O'Brien and Ryge, J Prosthet Dent, Nov–Dec, 1965; from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 524.

†Without bonding agent.

FIGURE 20–19
A, Poor wetting by porcelain with large contact angle.
B, Good wetting by porcelain with small contact angle.
(From O'Brien and Ryge, J Prosth Dent, Nov.-Dec. 1965; reproduced from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 525.)



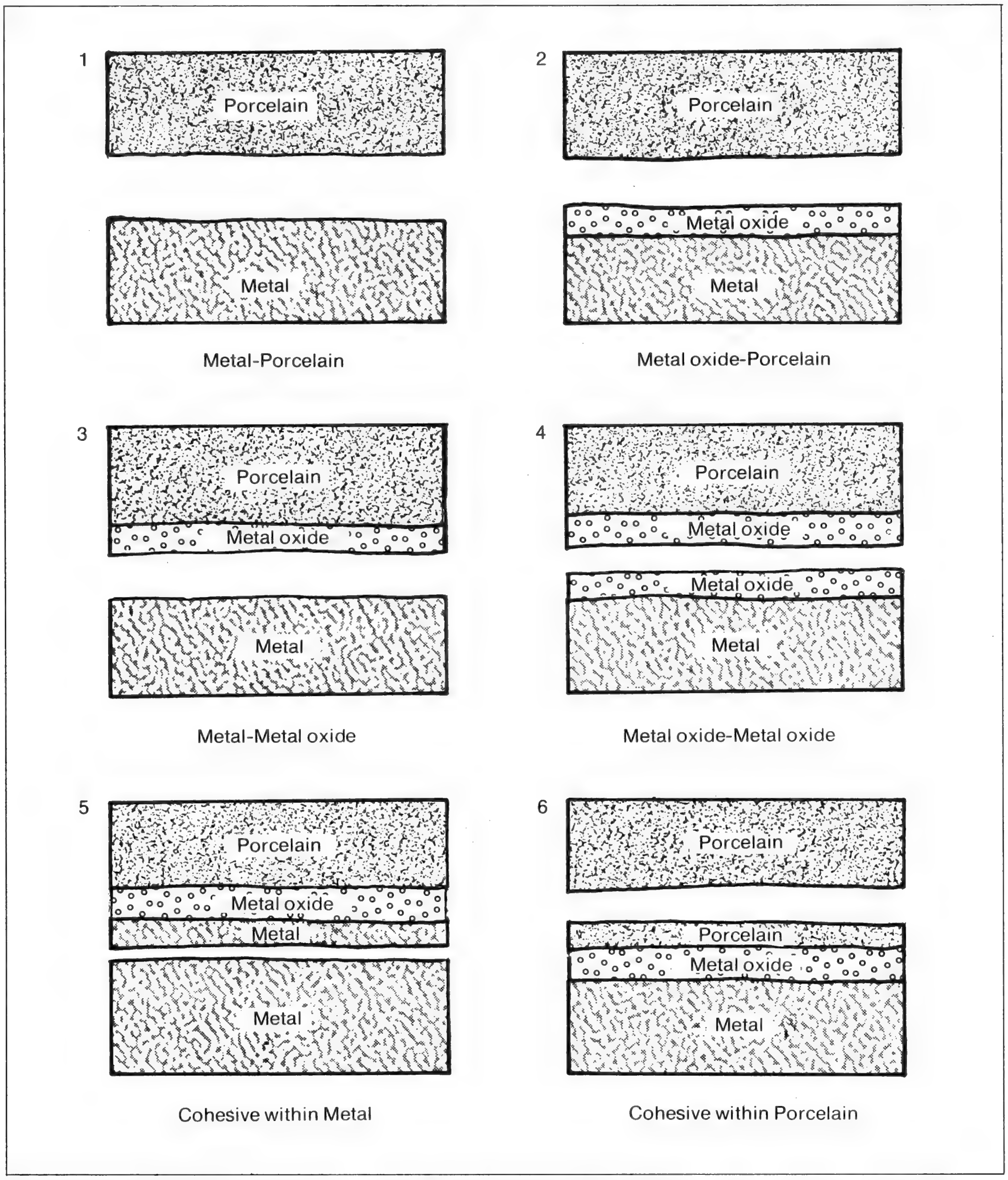


FIGURE 20–20 Type of bond failure in metal-ceramic material. (After O'Brien, WJ: Cohesive Plateau Theory of Porcelain-Alloy Bonding. *In* Dental Porcelain—State of the Art. University of Southern California Conference Proceedings, 1977. Originally reproduced from McLean, JW: The Science and Art of Dental Ceramics. Vol. 1. Chicago, Quintessence Publ. Co., 1979, p. 84; reproduced here from Phillips, RW: Skinner's Science of Dental Materials. 8th ed. Philadelphia, W. B. Saunders Company, 1982, p. 527.)

the metals or alloys. Material A appears to exhibit the best wetting properties relative to the adherent, with materials B and E being comparable. It is evident from the changes in contact angle when the porcelains are applied to platinum and palladium that the composition of the metal adherent is important. The difference between poor wetting and good wetting is illustrated in Figure 20–19.

The adhesion between two surfaces may be stronger than the strength of the adhesive, as happens to be the case in the adhesion between porcelain and noble metal alloys under tensile stress. The fracture generally occurs in the porcelain. As mentioned previously, base metal–porcelain failures generally occur at the interface.

Another very important requisite is that the porcelain and metal have compatible linear coefficients of thermal expansion. If the expansion coefficients are not essentially equal, radial stresses may occur that weaken the porcelain as well as the bond. For example, a difference in the coefficients of thermal expansion of only 3×10^{-6} per degree Fahrenheit can produce a shear stress of 2800 kg per sq cm (39,800 psi) in a gold-porcelain interface with the temperature changes from 954° C (1750° F) to room temperature. The shear resistance to failure is not greater than approximately 720 kg per sq cm (10,300 psi). Therefore, these thermal stresses would probably cause a spontaneous rupture of the bond.

Even with good quality control, the order of residual stress has been calculated to be in the order of 210 kg per sq cm (3000 psi). The occlusal stresses on the restoration would, of course, be added to these residual thermal stresses. However, fracture is unlikely to occur except in cases of extreme stress concentration or an incorrect occlusal relationship.

Compressive Stresses

Compressive stresses set up during the cooling of the sintered porcelain veneer also play a part in improving the bond strength. Metal-ceramic systems are deliberately designed with a very small degree of thermal mismatch in order to leave the porcelain in a state of compression.

Bond Strength

A variety of tests have been advocated for measuring the strength of the metal-ceramic bond, as noted earlier. None can be regarded as providing an exact measure of the adhesion of porcelain to metal except in cases in which the metal-porcelain couple is so exactly matched thermally as to be totally stress-free, which is a situation that is virtually impossible to attain. Even then, the adhesive strength would have to be lower than the strength of the porcelain itself.

Another approach has been suggested as more realistic than shear testing of the bond. This is to assess the location at which the failure occurs, either through the porcelain (cohesive) or a mixture of cohesive and adhesive failure, that is, part interfacial and part through the porcelain. In the absence of tensile failure through the porcelain, as in the noble alloy system, McLean* states that the "clinical safety of any metal-ceramic system must be suspect since the maximum possible strength is not being achieved and is likely to be variable depending on the precise conditions of preparation of the restoration."

A study of the interfacial separation following fracture is necessary in order to determine the weakest layer. A classification has been made of the various types of porcelain-enamel failures, as seen in Figure 20–20. Obviously, failure can occur cohesively within the porcelain or metal or in the various oxide interfaces.

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*McLean, JW. The Science and Art of Dental Ceramics. Vol. 1, Chicago, Quintessence Publ. Co., 1979, p. 82.

21
The All-Ceramic Crown

The porcelain jacket crown has long been the most esthetic full-coverage restoration available (Figs. 21–1 and 21–2). The all-ceramic composition is the major reason for its natural appearance. However, the lack of a metal casting to help resist porcelain fracture requires that certain design principles be incorporated into the tooth preparation so it can provide support for the restoration.

A type of porcelain jacket crown preparation was introduced in the 1880s by C. H. Land. Land and E. D. Spalding later modified the early concepts to improve clinical success and essentially developed the preparation as it is used today with a full shoulder finish line (Fig. 21–2A).

Since the internal adaptation of these restorations is best near the finish line, the shoulder provides vertical support through its flat surface. A chamfer finish line is more likely to produce tensile stress in the procelain when the restoration is seated, since contact on an inclined plane would tend to expand the ceramic material.

A shoulder of adequate width also produces a relatively substantial bulk of marginal porcelain. Consequently, there is less chance that porcelain will fracture at the margin during seating than with other finishing lines where the cervical porcelain is thinner. The greater marginal thickness also provides more uniformity in the cervical color of the restoration.

Attempts have been made over the years to strengthen porcelain jacket crowns by incorporating iridioplatinum metals and meshworks, but it was not until the 1960's that the restoration strength was significantly increased by reinforcement of the porcelain with aluminous oxide. The resulting material is referred to as *aluminous porcelain.* Recently, new materials and techniques have been developed in order to produce stronger all-ceramic crowns. Two of these techniques have even bonded a thin metal matrix to the porcelain in an attempt to strengthen the crown. However, none of these procedures has eliminated the necessity for the prepared tooth to provide support for the restoration.

ANTERIOR TOOTH PREPARATION

Facial and Proximal Reduction

To produce an esthetic color match, the facial surface should be uniformly reduced by a minimum of 0.8 mm. The labioincisal portion of the preparation is an area that is frequently inadequately reduced, and this produces increased opacity in that area of the final resto-

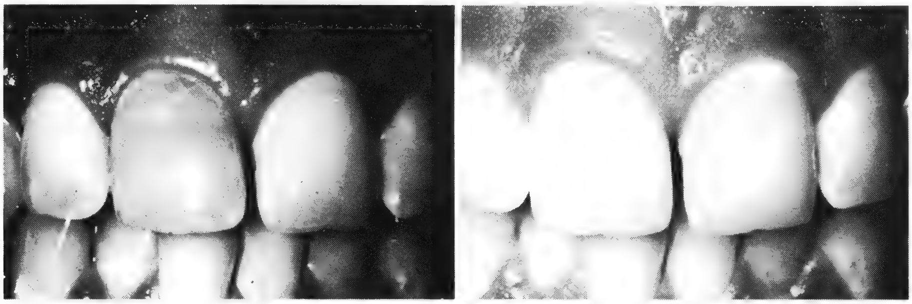


FIGURE 21–1

A, Discolored maxillary right central incisor.
B, Porcelain jacket crown cemented.

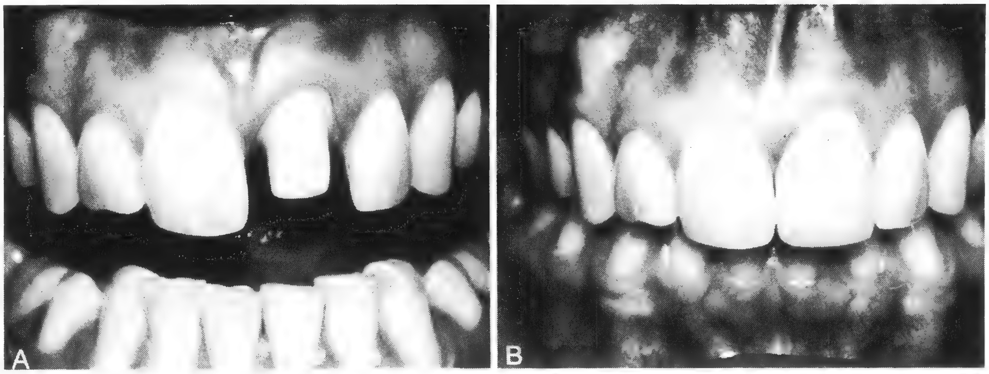


FIGURE 21–2

A, Maxillary left central incisor prepared for porcelain jacket crown.
B, Porcelain jacket crown cemented.

ration as a result of insufficient thickness of porcelain for proper color. Problems related to improper tooth reduction are more frequently encountered when the labial surface is reduced in one plane only.

The use of depth cuts that follow the unprepared tooth contour helps ensure more uniform facial reduction (Fig. 21–3). Also, removal of either the mesial or distal one-half of the facial surface aids in securing uniform reduction, since the reduced half can be visually compared with the intact portion of the tooth (Fig. 21–4A).

The depth cuts and all bulk reduction of tooth structure should be accomplished by use of a water spray and

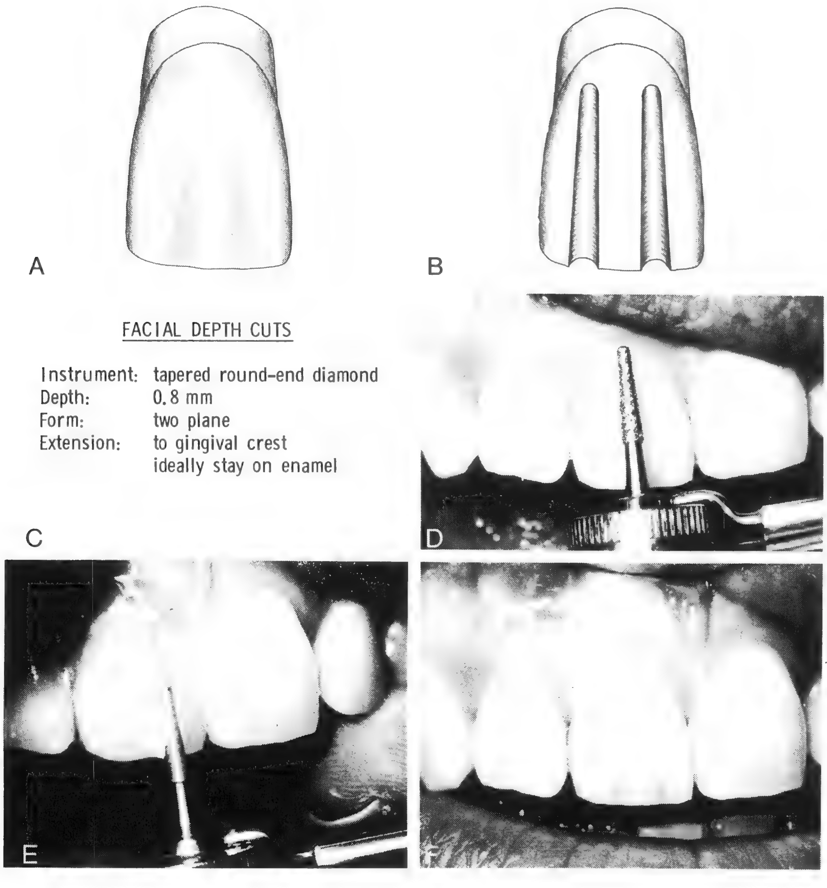


FIGURE 21–3

A, Maxillary central incisor prior to porcelain jacket preparation.
B, Facial depth cuts.
C, Procedures for producing facial depth cuts.
D, Tapered round-end diamond instrument aligned with cervical tooth contour.
E, Incisal portion of depth cut placed parallel to incisal tooth contour. Note the use of a water spray.
F, Two depth cuts placed.

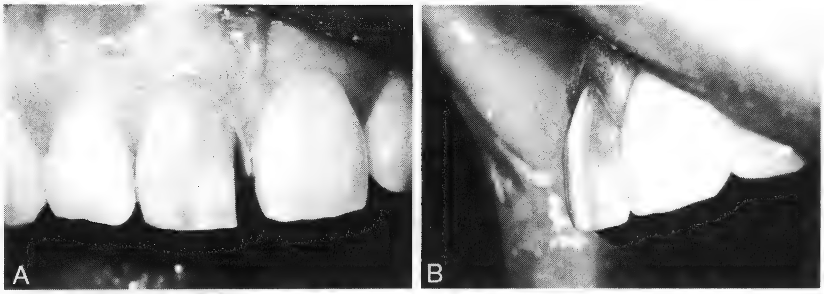


FIGURE 21–4
A, Mesial one-half of tooth reduced.
B, Proximal view showing uniformity of facial reduction.

either a coarse-grit* or medium-grit† tapered round-end diamond instrument. These instruments have a tip diameter of approximately 0.8 mm, and the pulpal depth is gauged by reducing the tooth until the instrument is within the external tooth contour. When the proximal space is limited, a smaller-diameter diamond instrument‡ may have to be used to prevent damage to adjacent teeth. These instruments produce a preliminary finish line in the form of a heavy chamfer. After the gross reduction of all tooth surfaces has been completed, the final apical position and shoulder form of the finish line can be established.

Depth cuts should follow the facial tooth contour, which produces two distinctly different angulations to the incisal and cervical aspects of each depth cut. Generally, two or three depth cuts are equally spaced over the mesiodistal dimension of the facial surface.

The cuts are extended pulpally until they closely approximate the desired 0.8 mm but are slightly shallow. This allows subsequent refinement of the preparation to achieve the final depth without excessive facial reduction. The cervical aspect of the depth cut is placed first but at this time should not be extended subgingivally in order to prevent soft tissue trauma by cutting the gingiva with rotary instruments. The incisal portion of the depth cut is completed to a similar depth but follows the angulation of the incisal one-half of the unprepared tooth.

The tooth structure located between the depth cuts is now removed, and the reduction is continued around the facioproximal line angles and through the proximal surface (Fig. 21–5). Particular care must be exercised to maintain a supragingival finish line during this initial reduction as the diamond instrument is guided interproximally from the facial surface. The instrument should follow the gingival contour, which generally requires moving the instrument incisally as the reduction progresses lingually in order to avoid cutting of the interdental papilla. Also, this prevents the initial finish line from extending excessively deeply into the gingival crevice.

The amount of tooth structure removed from the mesial and distal surfaces should be approximately the same. This equality of reduction allows nearly the same resistance to rotation of the restoration when forces are applied to either marginal ridge of the restoration. An overreduced proximal surface reduces resistance to rotation on that side. The weakness is related to the fact that the marginal ridge of the final restoration is unnecessarily far away from the prepared tooth. This relationship allows more leverage to be developed on the crown when occlusal forces are applied to that marginal ridge.

Equal proximal reduction also allows development of more uniform proximal translucency similar to that of natural teeth.

The actual amount of proximal reduction varies with the crown form. Less overall tooth structure is removed from a square-shaped crown when a proximal shoulder 0.8 mm deep is established than on a tooth with a tapered crown form. In addition, from the standpoint of adverse pulpal response, it is not desirable to establish normal interproximal shoulder depth on tapered teeth with large pulp horns.

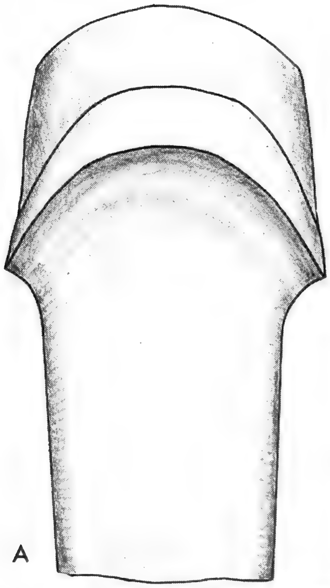
The two proximal surfaces should converge only slightly toward the incisal edge. Three to 5 degrees of taper between these walls is ideal for retention. Extreme parallelism should be avoided with all-ceramic restorations, since any binding of the restoration during seating can cause fracture.

Incisal Reduction

An incisal edge reduction of 1.5 mm is necessary for reproduction of incisal translucency, and the use of incisal depth cuts promotes adequate and uniform reduction (Fig. 21–6). Additional shortening in order to achieve greater translucency is acceptable when the crown has a longer than average incisocervical dimension. However, when a short crown form is encountered, reduction beyond 1.5 mm can weaken the restoration, since the final incisocervical preparation length may not be two-thirds to three-quarters that of the final restoration (as discussed in Chapter 19).

Next, the incisal edge is reduced by using the depth cuts as a gauge (Fig. 21–7). The faciolingual inclination of the reduced surface should be approximately perpendicular to the line of force being applied by the opposing teeth. This relationship provides additional support for the restoration when forces are applied near the incisal edge. The mesiodistal angulation of the incisal reduction should follow the incisal edge curvature prior to reduction, which allows uniform incisal translucency to be developed in the restoration.

*Two striper 767.7C, Premier Dental Products Company, Philadelphia, PA 19107.
†Blu-White 1 DT, Teledyne Densco, Denver, CO 80207.
‡Blu-White ½ DT, Teledyne Densco, Denver, CO 80207.



FACIAL AND PROXIMAL REDUCTION

Instrument: tapered round - end diamond
Depth: 0.8 mm
Form: two planes facially
follow gingival contour
Extension: to linguoproximal line angle
to gingival crest
ideally stay on enamel

B

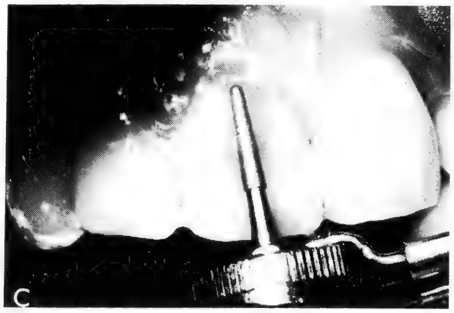
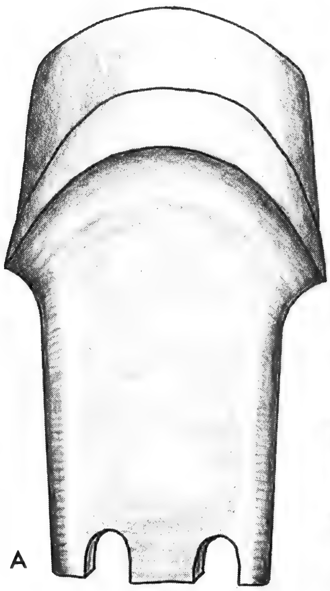


FIGURE 21–5

A, Facial and proximal reduction.
B, Procedures for facial and proximal reduction.
C, Tooth structure removed between facial depth cuts.
D, Both proximal surfaces reduced.



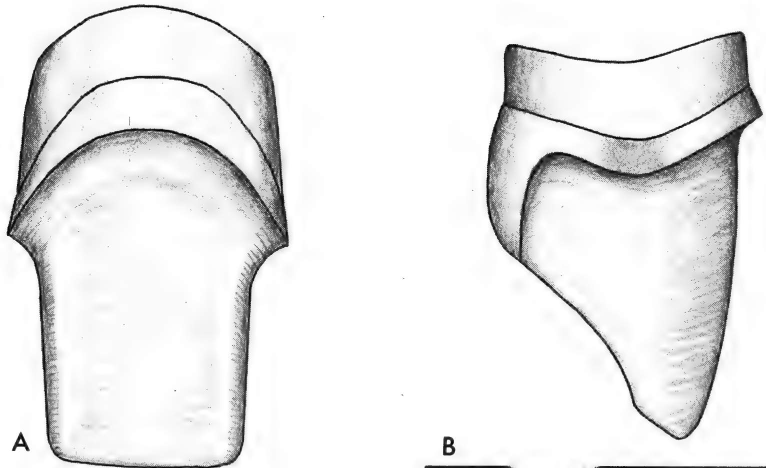
INCISAL DEPTH CUTS

Instrument: tapered round - end instrument
Depth: 1.5 mm

B

FIGURE 21–6

A, Incisal depth cuts.
B, Procedures for incisal depth cuts.
C, Depth cuts placed with tapered round-end diamond instrument.



A B

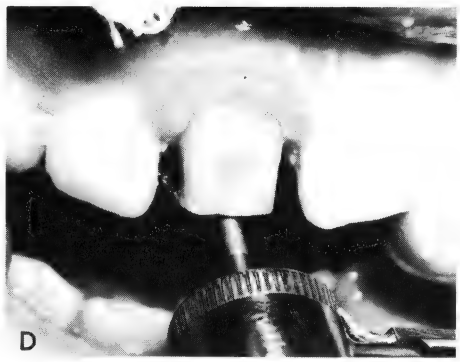


FIGURE 21–7
A, Incisal reduction, facial view.
B, Incisal reduction, proximal view.
C, Procedures for incisal reduction.
D, Incisal reduction completed by reducing tooth to base of depth cuts.

INCISAL REDUCTION

Instrument:	tapered round - end diamond
Depth:	1.5 mm
Form:	follow mesiodistal curvature follow faciolingual slope

C D

Lingual Reduction—Cingulum

The lingual surface cervical to the cingulum is reduced by using the same tapered round-end diamond instrument to form a lingual wall that establishes retention with the facial surface (Fig. 21–8). The lingual wall formed during this reduction should converge incisally relative to the cervical aspect of the facial surface until the desired 3 to 5 degrees of taper is developed. Again, extreme parallelism is to be avoided.

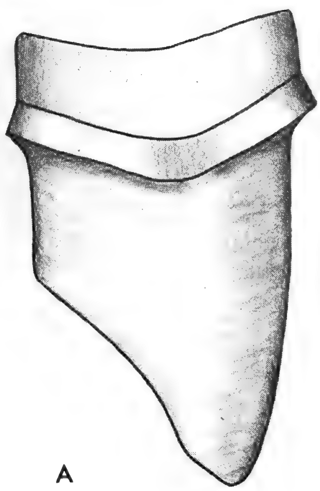
Placing the diamond instrument against the cervical portion of the facial surface establishes the proper faciolingual alignment of the cutting instrument. The instrument is moved from the facial surface to the lingual surface, and depth cuts are placed to ensure that the completed preparation also has adequate reduction in this area. A heavy chamfer finish line is established to join the previously formed proximal finish line.

If the gingiva covers a large portion of the lingual surface, it may be necessary to remove soft tissue by

LINGUAL REDUCTION - CINGULUM

Instrument:	tapered round -end diamond
Depth:	0.8 mm
Form:	follow gingival contour
Extension:	join shoulder proximally ideally stay supragingival ideally stay on enamel

B



A

C

FIGURE 21–8
A, Lingual reduction at the cingulum.
B, Procedures for lingual reduction—cingulum.
C, Heavy chamfer being established lingually with tapered round-end diamond instrument.

means of electrosurgery or periodontal surgery in order to produce a sufficiently long and retentive lingual wall. Whenever possible, the finish line should be terminated on enamel.

Lingual Reduction—Occlusion

The concave portion of the lingual surface must be reduced so that 1 mm of clearance is achieved with the opposing teeth in centric occlusion and throughout protrusive mandibular movements (Fig. 21–9). Failure to achieve this amount of reduction significantly weakens the completed restoration. A wheel-* or football-shaped† diamond instrument compatible with the curvature of the lingual concavity is recommended for this reduction.

*Two Striper 860F, Premier Dental Products Company, Philadelphia, PA 19107.

†Number 368, Brasseler USA, Savannah, GA 31405.

Shoulder Formation

A shoulder finish line is now formed in place of the heavy chamfer (Fig. 21–10). A carbide bur with parallel sides and a square end is recommended to create the shoulder. The presence of spiral flutes and the absence of crosscuts promote the formation of a smooth preparation as the shoulder is established. A number 56 or 56L carbide bur is ideal for this aspect of the preparation.

The heavy chamfer finish line is terminated at the crest of the gingiva in order to prevent soft tissue damage from rotary instruments. However, it is often necessary to extend the completed shoulder finish line below the crest of the gingival tissue to gain adequate retention, to cover existing restorations, or for esthetic reasons. Whenever possible, the subgingival extension should be limited to 0.5 to 1 mm.

A subgingival finish line location requires apical repositioning of the existing finish line as it is changed from a chamfer to a shoulder. In order to prevent gingival damage, retraction cord should be placed into

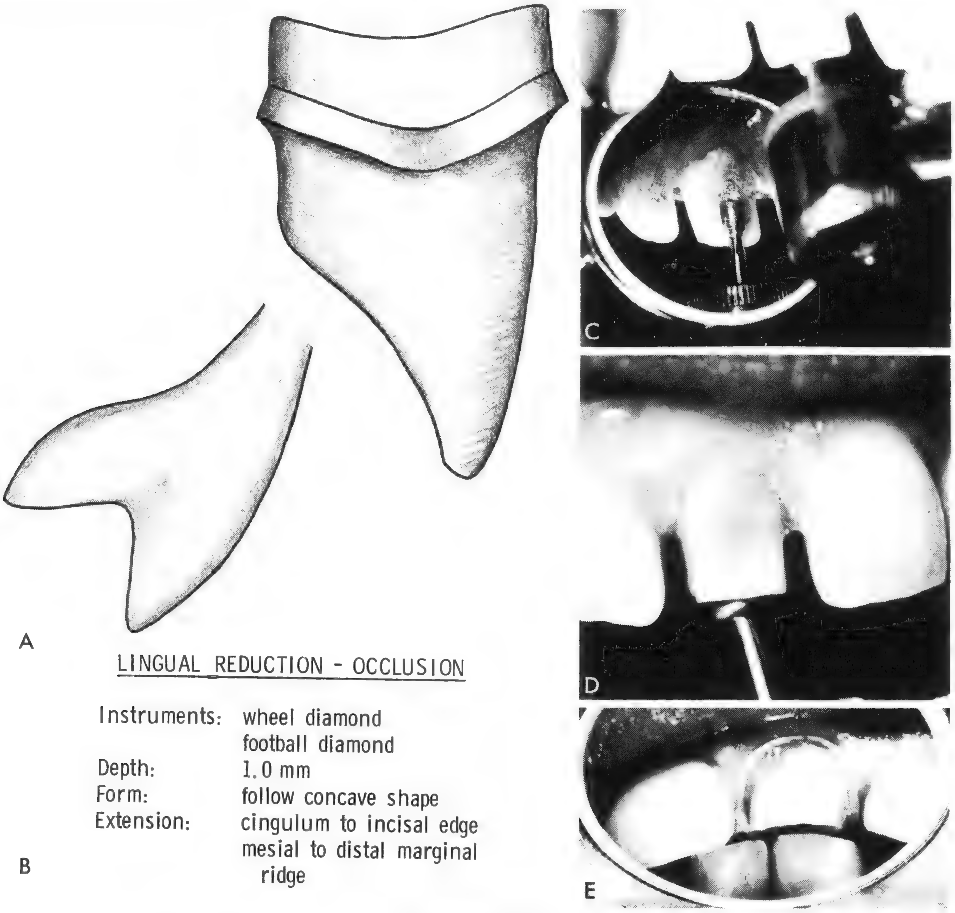
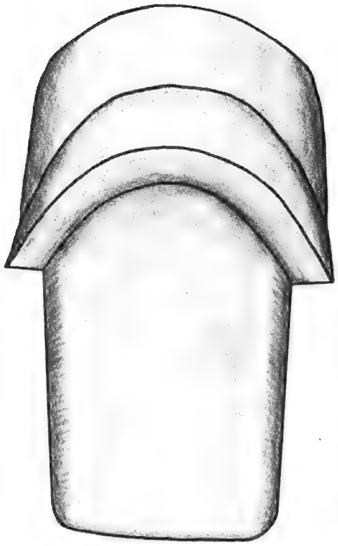


FIGURE 21–9

A, Lingual reduction for occlusion.
B, Procedures for lingual reduction—occlusion.
C, Football-shaped diamond, which is compatible with concave lingual tooth form.
D, Wheel-shaped diamond used for lingual reduction.
E, Occlusal clearance being checked.



A

SHOULDER FORMATION

Instruments:	parallel walled carbide bur spiral flutes, no crosscuts 56 or 56L
Depth:	0.8 mm
Form:	follow gingival contour
Extension:	0.5 to 1.0 mm subgingival ideally stay on enamel

B

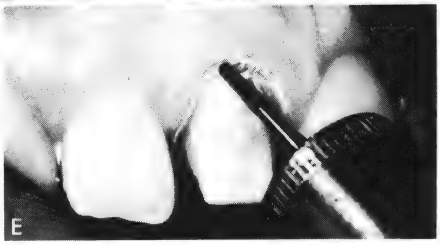


FIGURE 21–10
A, Shoulder formation.
B, Procedures for shoulder formation.
C, Retraction cord being inserted into gingival crevice with periodontal probe.
D, Shoulder depth established and axial wall smoothed.
E, Cervical floor of shoulder smoothed with tip of bur.

the gingival crevice (Fig. 21–10C). The cord generally produces 1 mm of gingival displacement, which allows the shoulder finish line to be formed and located cervically without trauma from the rotary instruments. Extension of the finish line to the level of the retraction cord results in a subgingival margin when the cord is removed and the soft tissue returns to its normal position.

Ideally, the finish line should be terminated on enamel and not extended onto the root surface, on which less tooth structure is available for reduction.

The square-ended carbide bur is extended pulpally to form the required 0.8-mm shoulder depth and moved around the circumference of the tooth at the desired cervical location. As the bur contacts the axial walls, they are also refined, and the final smoothness and degree of taper are achieved (Fig. 21–10D).

At this point, the cervical floor of the shoulder often possesses irregular areas, which require further refinement. The finalized shoulder must be very smooth and not exhibit extreme undulations around the circumference of the tooth, which would interfere with accurate adaptation of the final restoration. The cervical floor of the shoulder is refined by using the tip of the carbide bur to follow the marginal contour (Fig. 21–10E). Contact with the axial wall should be avoided during this process to prevent formation of a cervical undercut. For this reason, an end-cutting bur may be advantageous, since axial wall contact is not as likely to produce an undercut.

Rounding Line Angles and Smoothing the Preparation

Final preparation smoothness and form are accomplished with both rotary and hand instruments (Fig. 21–11). A hoe, hatchet, or binangle chisel of the proper blade width provides access to all portions of the finish line. An 8-4-10 hoe has a blade 0.8 mm wide and can be used as a gauge to shoulder depth as well as for final smoothing of the finish line (Fig. 21–11D).

The axial walls were gently smoothed when the shoulder finish line was established, but additional localized smoothing may be necessary using the carbide bur. The lingual surface and line angles also need smoothing and refinement. A wheel or tapered-cylinder carborundum stone is used to smooth the concave lingual surface and to round the sharp line angles at which the various surface reductions meet. The rounded line angles help to reduce stress concentration on the internal surface of the restoration that could lead to propagation of cracks. The mesiofacial and distofacial line angles may also require rounding but should not be eliminated, since they are useful in creating resistance to rotation of the restoration on the prepared tooth.

When these procedures are done, the preparation is complete, and with the described characteristics should provide good support for an esthetically pleasing restoration (Fig. 21–11E–H).

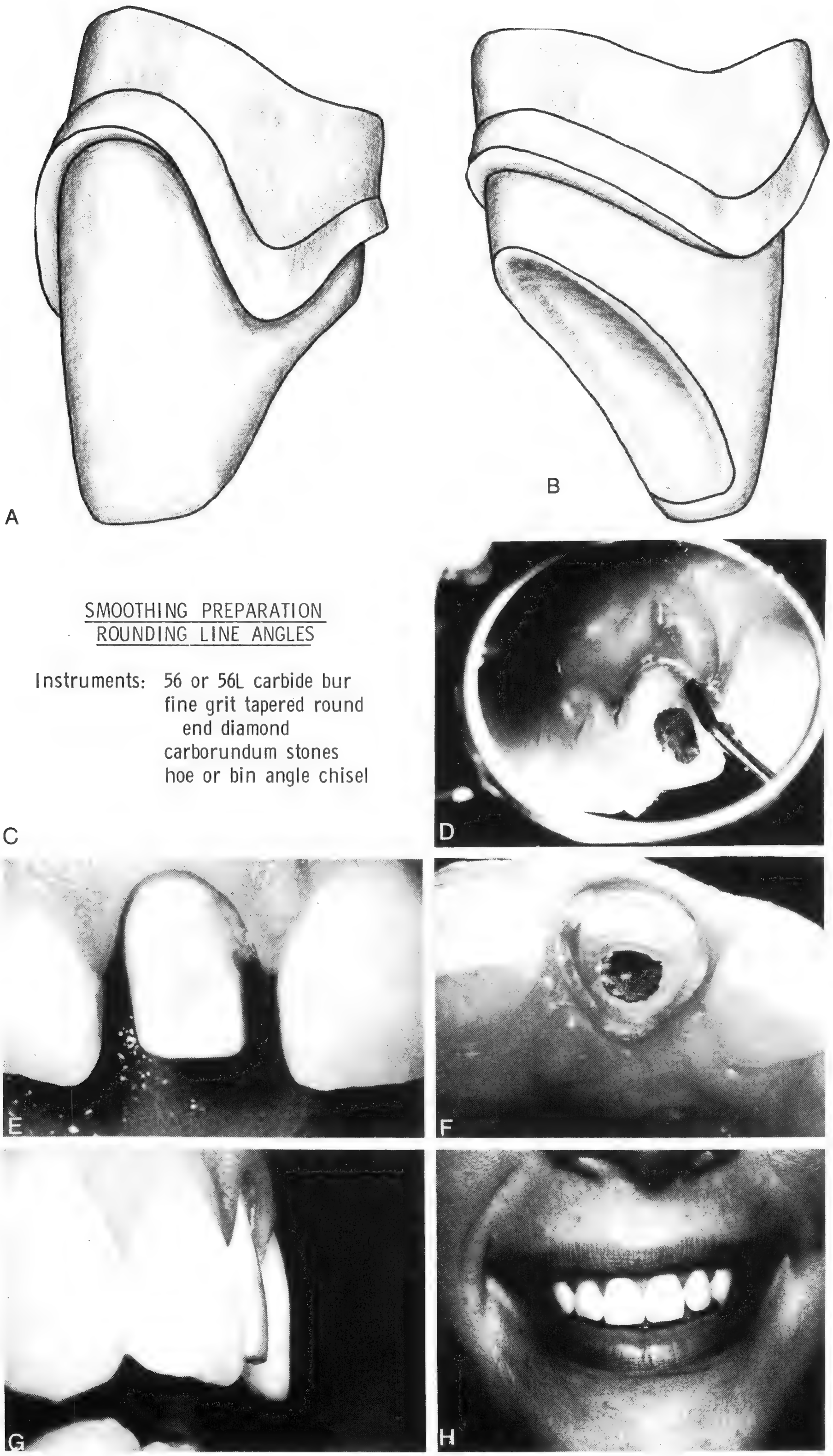


FIGURE 21–11

A, Preparation completed, facial view.
B, Preparation completed, lingual view.
C, Procedures for smoothing preparation and rounding line angles.
D, An 8-4-10 hoe smoothing the shoulder.
E, Completed preparation, facial view.
F, Completed preparation, incisal view.
G, Completed preparation, proximal view.
H, Porcelain jacket crown cemented on right central incisor.

FABRICATION PROCEDURES

Porcelain jacket crowns are all-ceramic restorations and do not contain metal when they are cemented. However, during the fabrication of the restoration, there is a metal form on which porcelain powders are condensed and fired. This form is developed from the prepared tooth and must retain the details of the preparation shape throughout the fabrication procedures. The form should also be easily removed from the porcelain after completion of the fabrication procedures. Platinum foil (0.0005 to 0.001 inch thick) satisfies these requirements and has become the commonly used type of metal form.

Originally, platinum foil was adapted directly in the mouth over the prepared tooth, but with indirect procedures it is adapted over a die of the prepared tooth.

Platinum foil can be adapted over a stone die, but a harder material is preferred, since a stone die can be damaged easily during foil adaptation. The procedures described in this chapter involve utilization of a silver-plated die.

The porcelain jacket crown fabrication technique is divided into the following sequential procedures: (1) formation of a silver-plated die, (2) development of a platinum foil matrix over the die, and (3) fabrication of the restoration on the foil matrix.

THE SILVER-PLATED DIE AND REMOVABLE DIE WORKING CAST

Platinum foil cannot be accurately adapted to a die that has an undercut area cervical to the margin. This is true because the platinum foil must be intimately adapted to the die, extend beyond the finish line, and yet be withdrawn incisally without distortion. The presence of a cervical undercut causes well-adapted foil to become locked in place so that removal without distortion is impossible.

Since it is essential that the plated die not possess any cervical undercut, the offending area must be blocked out prior to forming the silver-plated die, thereby preventing silver-plating of an impression taken directly from the mouth.

The cervical undercut is blocked out on the stone die obtained from the clinical impression. Next an impression is obtained of the blocked-out die, and is subsequently plated. In this manner, a silver-plated die is developed with no undercuts in the area in which platinum foil is to be adapted.

Blocking Out the Cervical Undercut

Wax is used to block out the cervical undercut on one die, while another die serves as a record of the contour of the natural tooth cervical to the finish line. It is also possible to wax out minor surface flaws on the die that would act as undercuts to the removal of the platinum foil matrix.

The wax is extended 3.0 mm apical to the most cervically located portion of the finishing line (Fig. 21–12). The wax is carried to this point around the entire circumference of the die. A slight incisal convergence is created, which is approximately equivalent to the taper of the preparation. A widely converging blockout or one greatly differing from the taper of the preparation makes subsequent foil adaptation more difficult.

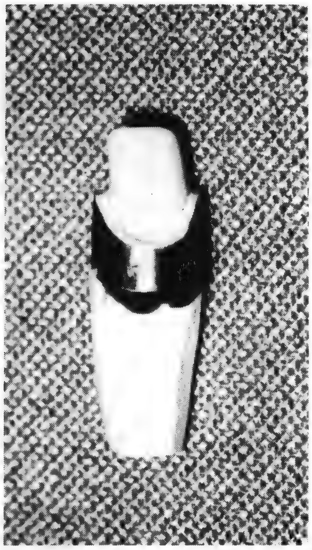


FIGURE 21–12 Cervical undercut blocked out on stone die with wax.

Obtaining the Laboratory Impression for Plating

An impression of the blocked out die is obtained in a copper band because of the need for a conductive material during the plating process. A copper band is selected that is about 2 mm larger than the circumference of the blocked out die in the area of the wax apron (Fig. 21–13A).

The copper band is reinforced with a plug of compound so it is not distorted when the impression is removed from the die (Fig. 21–13B). The plug is formed by heating a stick of compound and placing some of the softened material in one end of the band. The band is rested on a hard surface while a pencil eraser is used to tamp the compound into close adaptation with it. When the compound hardens, excess material is removed so the copper band remains exposed around the perimeter of the compound plug for purposes of future electrical conductivity.

The die and wax apron should extend into the band without the incisal edge of the die touching the compound plug, since that would produce an impression with an irregular area that does not plate properly.

The internal aspect of the copper band and compound plug is coated with impression adhesive and allowed to dry (Fig. 21–13C). Polysulfide and poly (vinyl siloxane) impression materials work well for electroplating. The impression material is mixed and placed into the band. It can be applied over the die by syringe or placed around the die with an instrument. The die is seated into the band until the wax apron is within the copper band (Fig. 21–13D). The die should be left in the band for 20 minutes to ensure complete setting of the impression material at room temperature.

The excess impression material is trimmed away (Fig. 21–13E), and the die is removed from the impression (Fig. 21–13F).

Plating the Impression

The end of the copper band with the compound plug is placed onto an electrode so that the band contacts the

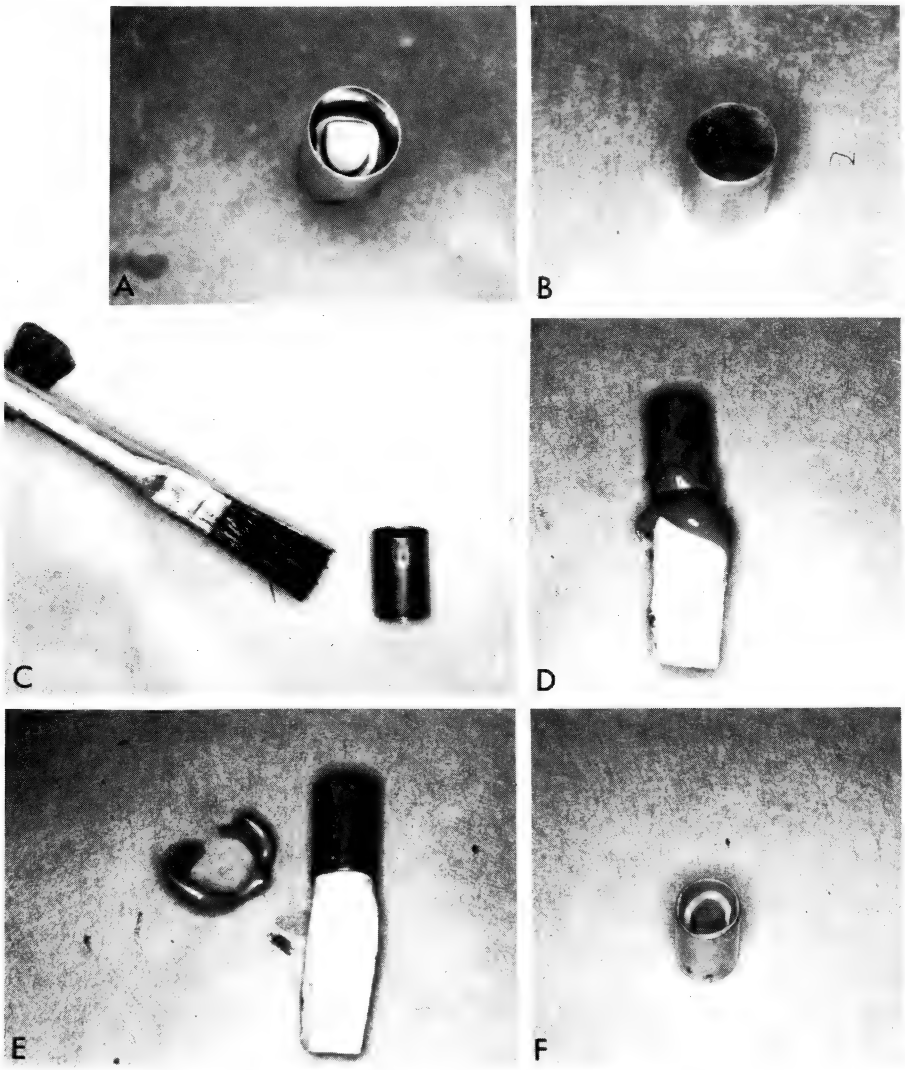


FIGURE 21–13 Impression for Silver-Plated Die

A, Copper band selected.
B, Compound plug placed in one end.
C, Adhesive applied.
D, Band filled with impression material seated over die.
E, Excess impression material trimmed away.
F, Resulting impression.

metal electrode surface. Sticky wax is used to hold the band in position. A section of masking or autoclave tape is cut to extend 2 mm beyond the open end of the band and wrapped tightly around the band. Sticky wax is then made to flow over all exposed metal surfaces and tape seams (Fig. 21–14A). This prevents plating of the outside of the copper band, since all exposed metal surfaces would plate and interfere with the plating in the internal aspect of the impression.

Silver metallizing powder is brushed into the impression and onto the end of the copper band (Fig. 21–14B). A gentle blast of air is used to remove excess powder.

The impression is filled with plating solution by submerging the electrode in the plating bath and allowing the solution to slowly run in from one side. It is easy to trap air bubbles in the sharper aspects of the impression, creating areas that do not plate. When this occurs, the solution can be poured out of the impression, and a gentle tap generally bursts the air bubble. Then the impression can be carefully refilled with solution. Alternately, a trapped air bubble can be eliminated by contacting it and dislodging it with a small metal instrument.

The electrode is completely submerged in the solution, and the plater is turned on. Two-tenths of a milliampere per electrode for a period of 8 hours produces a satisfactory layer of plating.

It is advisable to verify that there is good electrical contact after the electrode has been placed in the plating bath. If the plating process is progressing satisfactorily, the inside of the impression loses its silver color and turns white after 10 to 15 minutes.

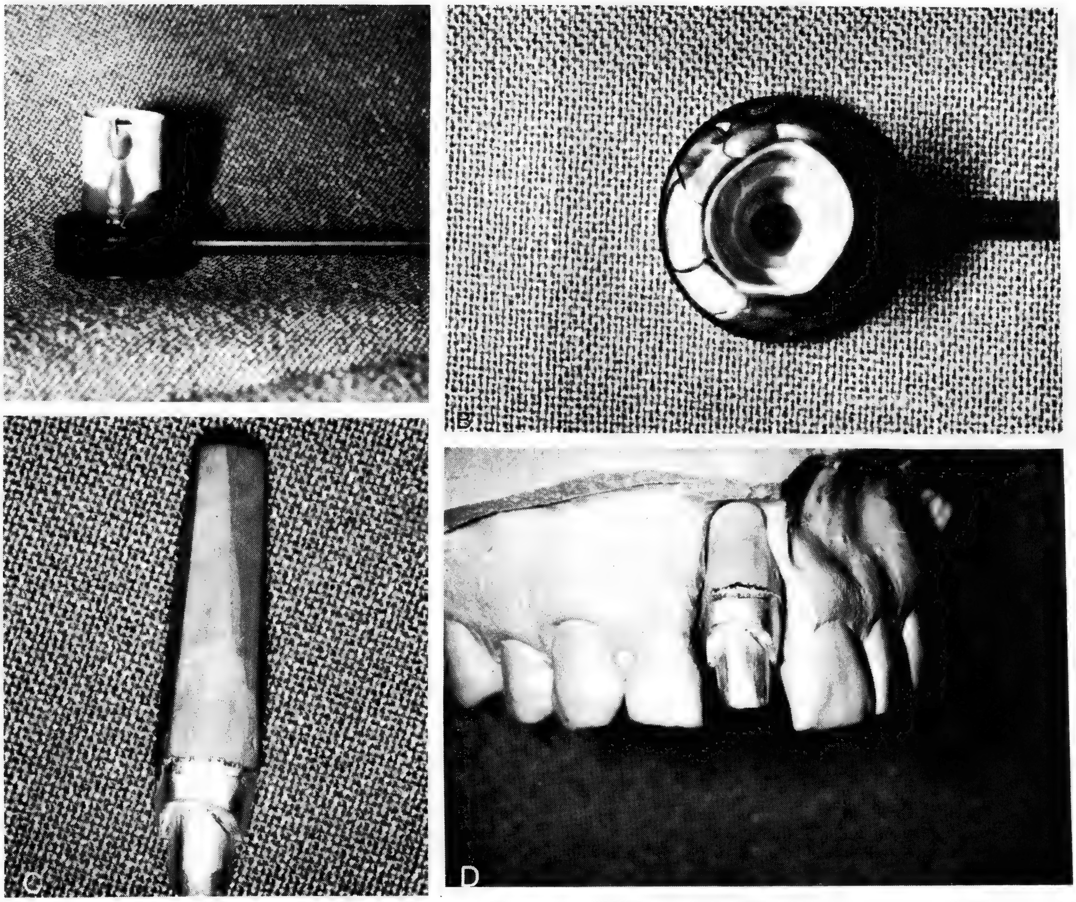


FIGURE 21–14 Plating the Die and Forming the Working Cast

A, Copper band attached to plating electrode.
B, Silver metallizing powder brushed over impression material and rim of copper band.
C, Silver-plated die with tapered root form.
D, Silver-plated die in removable die working cast.

After the plating is complete, the electrode is removed, rinsed, and dried. Additional tape is placed around the copper band so a root can be formed on the plated die when vacuum-mixed dental stone is poured inside the impression.

The stone provides support for the thin layer of silver and should be introduced slowly and carefully into the impression to avoid trapping of air between the stone and the silver. That would permit collapse of the silver layer when force is subsequently applied to the surface.

After the stone sets, the impression is separated from the die, and the root is tapered apically (Fig. 21–14C). Three millimeters of silver should be left apical to the margin.

It is advisable to form a wax pattern on the stone die and to transfer it to the silver-plated die to verify the dimensional accuracy of the plated die. The wax pattern should fit on the silver-plated die accurately and without fracturing.

Removable Die Working Cast

The die is placed back into the previously obtained full-arch clinical impression, and any impression material is removed that interferes with complete seating. The die is stabilized in the impression by using sticky wax.

The stone root is lubricated with petroleum jelly, and the impression is poured in stone. The impression is separated from the hardened cast and placed in hot water to soften the sticky wax and allow the silver-plated die to be removed from the cast (Fig. 21–14D).

Platinum Foil Matrix Formation

A thin layer of platinum foil is adapted to the die to produce a matrix on which porcelain powders can be applied.

Platinum foil, 0.001 inch thick, is well suited for matrix formation. The foil is cut so a size and form are obtained that can be wrapped around the die, allowing enough excess material that the ends can be joined proximally to produce a tinner's joint (Fig. 21–15). To facilitate the foil adaptation, either proximal surface is the preferred location for the tinner's joint.

The platinum foil is pulled around the die with the ends drawn together by cotton pliers (Fig. 21–16A, B,

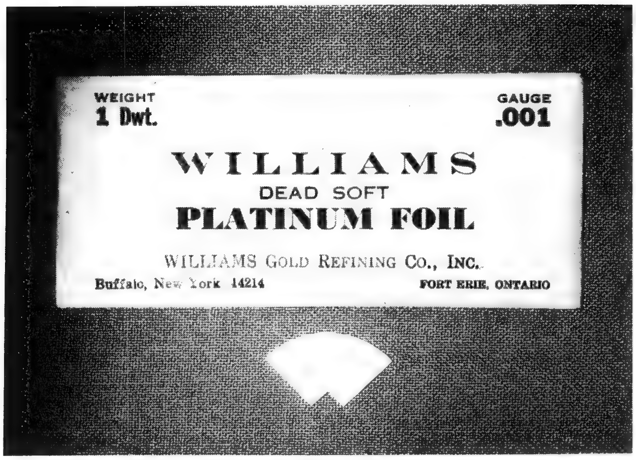


FIGURE 21–15 Platinum foil and template.

C). The ends are then trimmed with scissors so they extend only 2 mm laterally and incisally to the die (Fig. 21–16D, E). One of the ends is further shortened 1 mm (Fig. 21–16F). The 2-mm extension is folded over the 1-mm extension (Fig. 21–16G), and the assembly is folded flat against the proximal surface to produce the tinner's joint (Fig. 21–16H).

A tinner's joint can also be formed incisally, although some individuals choose to lap one end over the other without forming a joint (Fig. 21–17). The matrix is removed from the die and trimmed so only 2 mm of foil extends cervical to the finish line.

The final adaptation to the die involves working the platinum foil into intimate contact with all the surfaces of the die. One of the difficult aspects of this adaptation is getting the foil into the internal angle of the shoulder without tearing the foil. From the start of the adaptation process, all the excess foil from above and below this angle should be gradually and carefully worked toward this area (Fig. 21–18A).

An instrument such as a bluntly pointed orangewood stick (Fig, 21–18B) can be used for the initial adaptation, and then other less blunt instruments such as a DPT 6 instrument can be used for the final adaptation (Fig. 21–18C). Once the foil is adapted to the internal angle, it is thoroughly burnished to ensure good axial and marginal adaptation (Fig. 21–18D). The adapted matrix should have no tendency to rotate on the die.

The matrix is removed and held up to a light source to inspect for tears and perforations. While a matrix with no tears is preferred, one with one or two small tears can be successfully used. A matrix with excessively long or multiple tears does not provide the necessary continuity and rigidity. It is advisable for the novice to practice forming a matrix with an easily adaptable material, such as tin foil, prior to trying platinum foil.

The use of a swage is recommended to enhance the overall final adaptation of the matrix. The die with the matrix in place is pushed into the modeling clay that fills the lower portion of the swage (Fig. 21–19A). A piece of rubber dam is placed over the matrix, and the clay-filled upper portion of the swage is pushed down over the die (Fig. 21–19B). The rubber dam prevents the clay from sticking to the matrix. A few sharp taps from a hammer on top compress the clay against the matrix and enhance the foil adaptation (Fig. 21–19C). After the matrix has been removed from the swage, the outer surface should be cleaned by wiping with a solvent such as chloroform.

Porcelain Application

Matrix Decontamination

The completed matrix should be decontaminated by heating in a furnace prior to porcelain application. This process eliminates oils and gases from the surface of the foil. The matrix is heated in a vacuum to a temperature 50° C (122° F) above the highest firing temperature of the porcelain and held there for 2 to 3 minutes. A temperature of 1149° C (2100° F) is commonly used for this purpose. Following this procedure, the decontaminated matrix must not be touched with the fingers. The use of a clean gauze square or other such material during handling prevents recontamination.

Core Formation

Porcelain jacket crowns are fabricated from a porcelain in which alumina (Al_2O_3) crystals have been dispersed throughout to increase the strength of the restoration. Different types of porcelains that vary in alumina content are used in building the restoration.

The first layer formed over the platinum foil matrix is known as the *core*. The core porcelain contains 40 to 50 per cent alumina and forms the structural foundation. Aluminous porcelain jacket crowns can be fabricated using only core porcelain as the foundation for the overlying dentin and enamel porcelains. Alternately, a piece of pure alumina (97 per cent alumina) can be incorporated into the core porcelain. It is located in the lingual portion of the core, in which the greatest occlusal forces are developed, and is used to increase the overall strength of the restoration by preventing propagation of cracks within it. Since pure alumina fuses at a point beyond the range of dental porcelain furnaces, it is supplied in an already fused form that is inserted into the core porcelain.

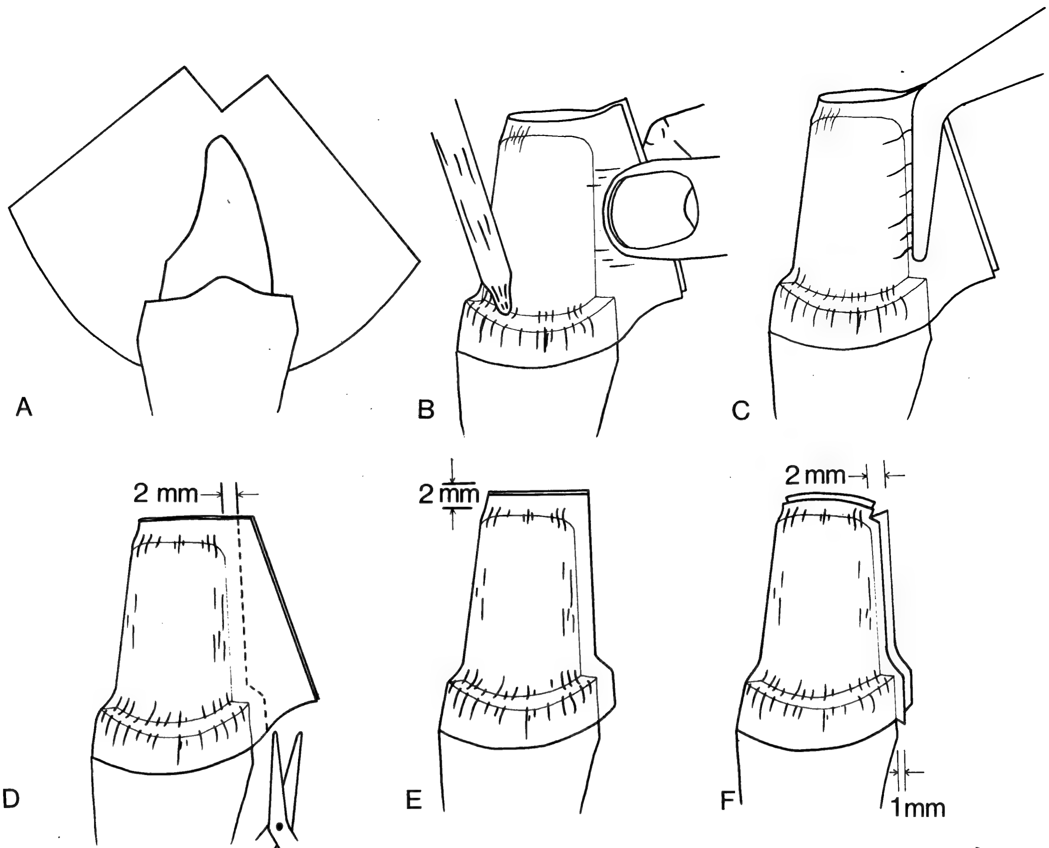
The fabrication technique described in this chapter involves the use of a pure alumina lingual insert. If an aluminous porcelain jacket crown is made without an insert, the technical procedures would be the same except for deletion of the steps dealing specifically with the insert. While well-controlled clinical studies have not been carried out to prove increased strength through the use of pure alumina inserts, many clinicians believe their experience indicates that inserts should be routinely used.

The first step in the formation of the core is shaping of the preformed insert. A slightly curved sheet of alumina is particularly suited for reinforcing the lingual surface of maxillary anterior teeth (Fig. 21–20A). Owing to their hardness, inserts are best shaped with diamond instruments.

The inserts are 0.6 mm thick and cannot be satisfactorily used in situations in which less than 1 mm of lingual reduction has been provided.

The insert is shaped to extend slightly laterally to the linguoproximal line angles of the preparation and slightly beyond the cingulum of the preparation. It should extend incisally only to the height of the labioincisal line angle.

Once the proper shape is achieved, the insert is



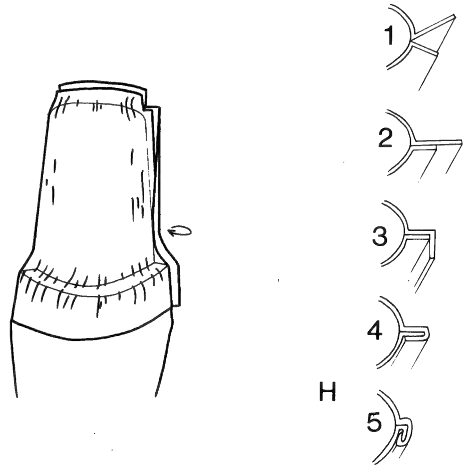


FIGURE 21–16 Platinum Foil Matrix Formation

A, Foil cut to size.
B, Foil pulled around die and worked into shoulder with blunt wooden stick.
C, Cinching up foil along proximal surface with cotton pliers.
D, Dotted line indicates where foil must be trimmed to create a 2-mm lateral extension.
E, Matrix trimmed proximally and incisally.
F, One end of matrix shortened so it projects 1 mm laterally and incisally.
G, Long end bent over short end.
H, Sequence of proximal tinner's joint formation viewed incisally.

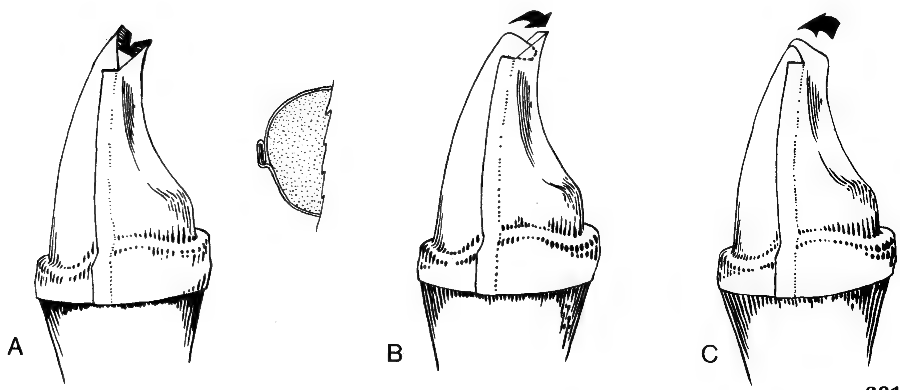


FIGURE 21–17 Platinum Foil Matrix Formation (Continued)

A, The two ends of the foil separated incisally.
B, Facial end tucked inside lingual end.
C, Lingual end lapped over facial end.

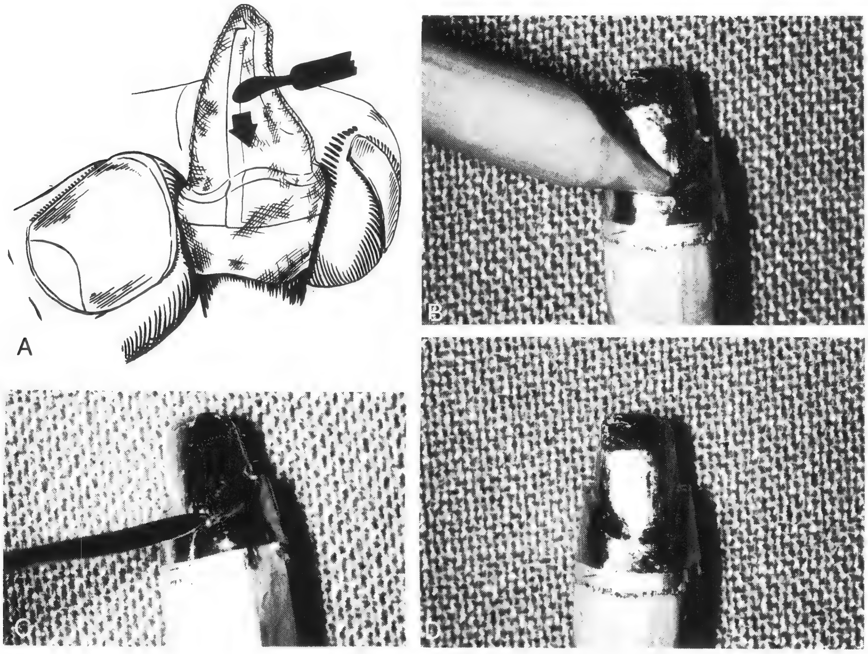


FIGURE 21–18 Platinum Foil Matrix Formation (Continued)

A, Excess foil located incisally being displaced cervically toward the shoulder.
B, Use of blunt orangewood stick.
C, DPT 6 waxing instrument used to carefully work foil against shoulder.
D, Burnishing complete.

cleansed of oils or contamination introduced during handling by wiping with chloroform or heating in a furnace.

A bead of the mixed core porcelain is picked up with a moistened brush and placed only on the lingual surface of the matrix (Fig. 21–20B). The shaped insert is placed on top of this porcelain, and vibration is used to ensure intimate contact.

There is a tendency for the insert to lift away from the core porcelain during firing. This problem is reduced by wrapping a thin strip of platinum foil snugly around the insert and the matrix and twisting it tightly to form

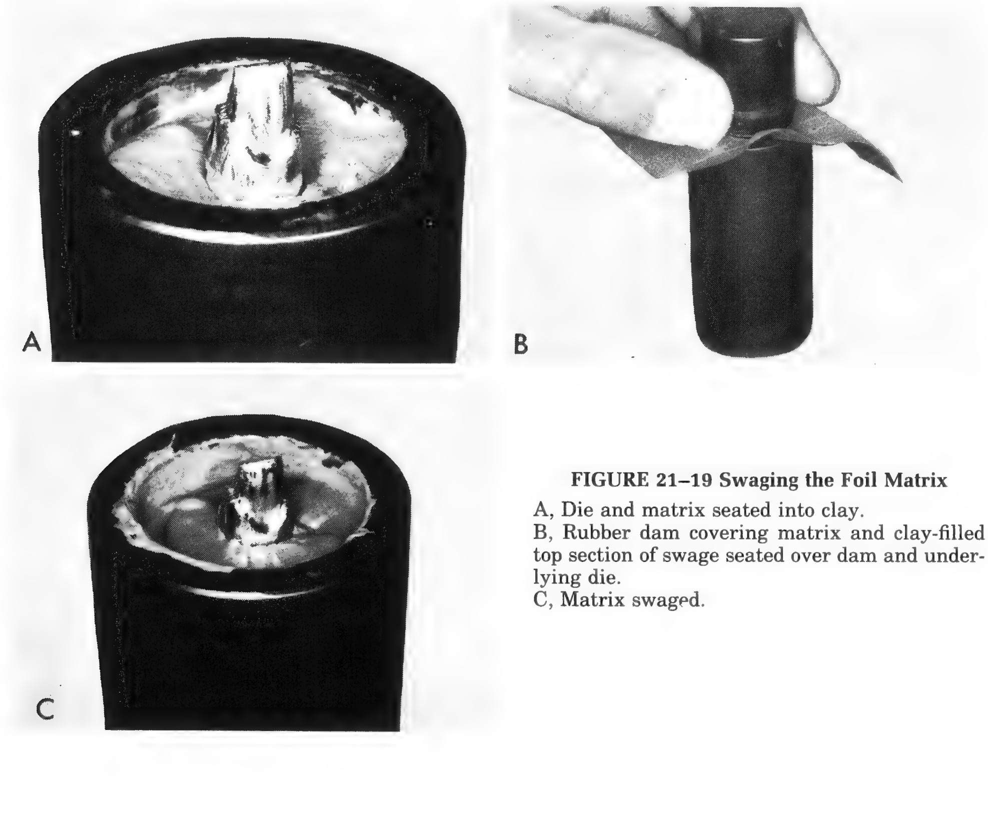


FIGURE 21–19 Swaging the Foil Matrix

A, Die and matrix seated into clay.
B, Rubber dam covering matrix and clay-filled top section of swage seated over dam and underlying die.
C, Matrix swaged.

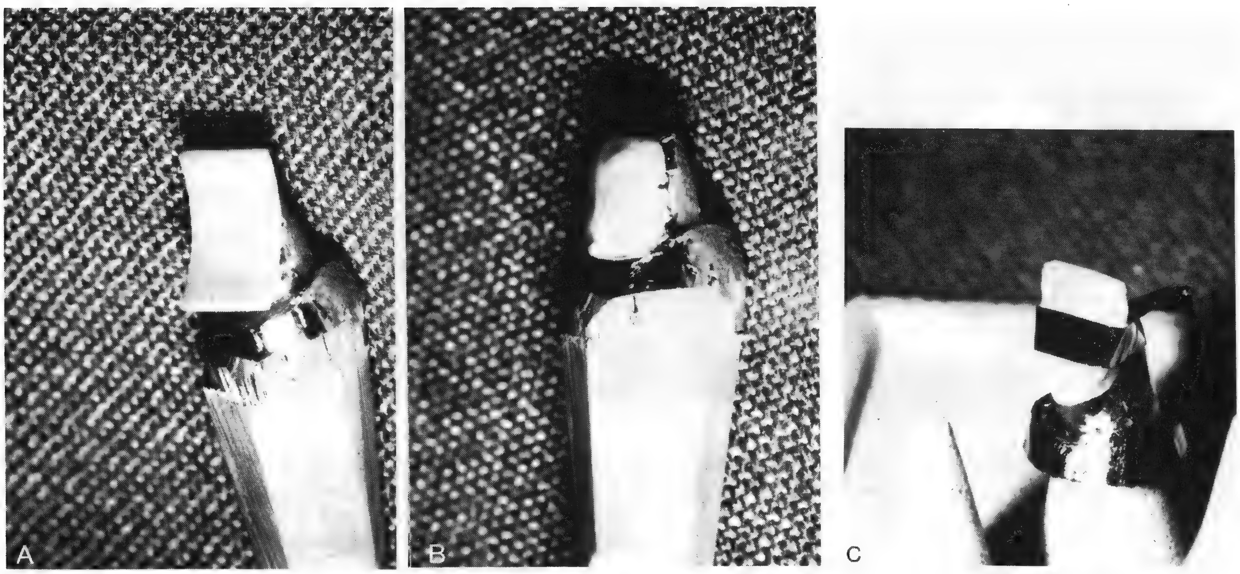


FIGURE 21–20 Placement of Alumina Insert
A, Preformed alumina insert resting on concave lingual surface.
B, Core porcelain applied to matrix.
C, Matrix with alumina insert and core porcelain seated on firing tray.

a band that helps eliminate separation. The matrix, insert, and foil strip are then removed from the die and placed on a firing tray (Fig. 21–20C). The porcelain is dried for 2 minutes and fired in a vacuum to the manufacturer's specified temperature.

After cooling to room temperature, the matrix is reseated on the die, and the foil band is removed so additional core porcelain can be added to complete the final core shape. The complete form is not established initially because it is difficult to place a band of platinum foil around a completed buildup without damage to the form of the axial surfaces.

The completed core buildup is formed so porcelain is as thick lingually as normal morphology and occlusion allow (Fig. 21–21). However, the fired core should be slightly out of occlusal contact with opposing teeth so it can be covered with dentin porcelain. Core porcelain does not glaze to form a smooth minimally abrasive surface, and therefore it must be covered with dentin porcelain, which can be properly glazed.

The core porcelain should be thinner facially (0.2 to 0.3 mm thick), since its opacity compromises the esthetic result if thicker layers are used. However, the additional masking power of a thicker facial layer of core material may be desirable when a jacket crown is placed over teeth with badly discolored dentin or over a cast metal post and core.

The core material is applied uniformly over the facial surface but should be stopped inside the restoration margin, since it does not glaze properly and would leave a rough area at the finish line. The margin is subsequently formed in dentin porcelain. The core thickness is gradually increased proximally to join the greater thickness established lingually. The increased interproximal thickness begins at the lingual extent of the proximal contact to allow room for interproximal translucency.

When the desired form is established through the addition of small increments of porcelain, the die is gently tapped until moisture rises to the surface. The excess moisture is removed with an absorbent material, and the process is repeated until the condensation procedure is complete.

The condensed core buildup is placed on a firing tray and dried for 5 minutes in front of the open furnace muffle. It is then fired in a vacuum according to the manufacturer's instructions. If cracks are observed in the fired porcelain, they must be filled in and the core refired until no cracks are visible. The core forms the structural foundation of the restoration and should be continuous, with as few flaws as possible. When the final patch bake reaches the proper firing temperature, the vacuum is released and the fired core removed so it can be inspected (Fig. 21–22).

If no cracks are observed, the core should be placed back inside the muffle, the furnace door closed, and the temperature allowed to rise to the proper firing range. The core is left at this temperature for an additional 20 minutes in air. This firing is performed in air, not in a vacuum, in order to prevent blistering of the porcelain. The purpose of the firing is to ensure good fusion of the alumina reinforcing crystals with the porcelain. The core exhibits more surface sheen after this firing (Fig. 21–23). Longer initial firing cycles are advocated by some individuals to achieve the proper degree of core fusion instead of a 20-minute air firing following completion of the core. Both methods are satisfactory as long as the proper degree of fusion is achieved.

If no cracks are observed in the core following the first firing cycle, it can then be subjected to the 20-

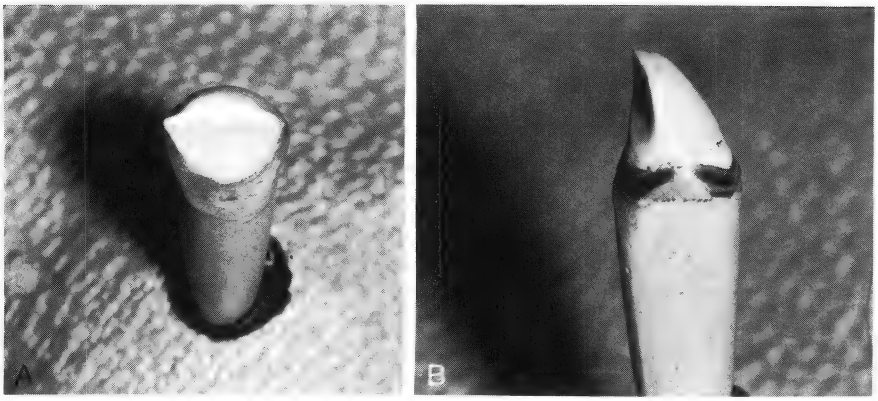


FIGURE 21–21 Initial Core Firing

A, Incisal view after initial firing of complete core form. Note the greater dimensions lingually.
B, Proximal view.

minute air firing cycle. The core is then complete and ready for the application of dentin and enamel porcelains.

Dentin and Enamel Application

After the crown form is built up in dentin and enamel, the porcelain must be separated from the platinum foil matrix at the margin to prevent fusion of the porcelain with the foil and distortion of the matrix when the firing shrinkage occurs. This separation is best accomplished by painting a thin layer of separating varnish* on the platinum foil at the margin. This material burns out during the firing, prevents the porcelain from sticking to the matrix, and creates a cervical ditch after firing. The ditch is filled in with porcelain powder following reburnishing of the matrix margin, and the restoration is refired to produce the final bulk of fired material. Shrinkage from this thin addition of porcelain does not produce discernible distortion of the platinum foil matrix. The space created by the ditched area also allows access for refinement and reburnishing of critical marginal areas of the matrix just prior to the final application of porcelain.

*Separator, Vita Zahnfabrik, Sackingen, West Germany.

The cervical ditch can also be formed after the dentin and enamel buildup by mechanically carving a separation between the platinum foil and condensed porcelain with a special thin-bladed metal instrument* or scalpel. The ditch is created by carefully pushing the blade between the foil and condensed porcelain in a pulpal direction. A series of in-and-out motions produces less disturbance and fracturing of the condensed porcelain than a circumferential scoring technique.

If a separating varnish is used, it is applied prior to application of the dentin and enamel porcelain, whereas mechanical ditching is done after completion of the buildup.

The platinum foil matrix with the completed core is placed on the silver-plated die and into the working cast. The proximal areas of adjacent teeth on the removable die working cast should be coated with a commercial sealing agent or nail polish. This prevents the stone cast from absorbing moisture from the porcelain during the buildup, which would disturb its handling characteristics.

The entire tooth form is established only in dentin porcelain, and a portion of the buildup is carved away in areas in which enamel translucency is required. Since

*Porcelain sculpturing instrument number 001 017, Belle de St. Claire, Van Nuys, CA 91406.

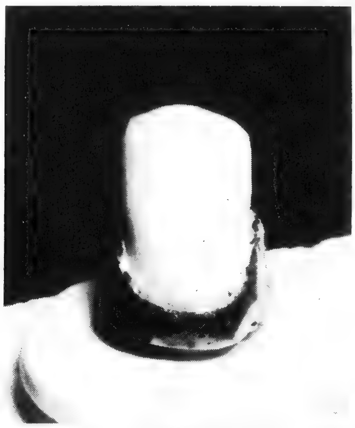


FIGURE 21–22 Second core firing. Facial view of core after patch bake.

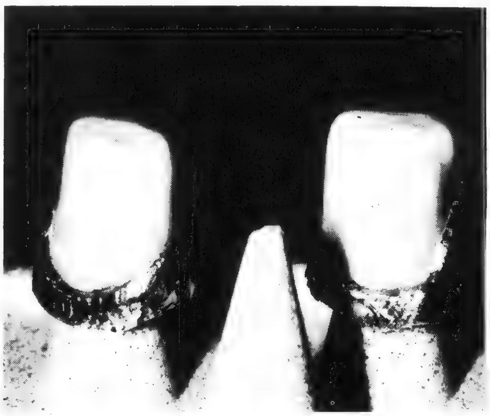


FIGURE 21–23 Appearance of core after final firing for 20 minutes in air. Note the surface sheen.

porcelain shrinks at firing, the dentin buildup should be about 20 per cent larger in all dimensions than the final restoration.

The core is moistened, and the oversized form of the tooth is incrementally established with only dentin porcelain (Fig. 21–24). The absorbent material can be held from the lingual side while the facial porcelain is applied. This process prevents moist porcelain from slumping over the lingual surface, since the absorbent material is readily available for the removal of excess moisture. If the buildup becomes too dry, the absorbent material is lifted from the porcelain until further moisture removal is needed.

Once the oversized facial form is established, the absorbent material is placed facially, and the lingual portion of the crown form is established.

A portion of the dentin porcelain is carved away with a scalpel or other sharp-bladed instrument so enamel porcelain can be applied over the dentin in areas in which translucency is desired (Fig. 21–25). A more natural-appearing blend of dentin and enamel is achieved by layering the two materials together rather than by firing the dentin and then grinding the porcelain to create room for enamel.

The extent of the cutback is based on a clinical evaluation and measurement of the location of translucency in the surrounding natural teeth (see Chapters 24 and 25). Generally, the greatest amount of translucency is in the incisal one-third and extends interproximally.

The cutback should produce the greatest faciolingual thickness of enamel at the incisal edge and then gradually taper out to the point at which the translucency terminates. Incisally it should extend to the faciolingual center of the incisal edge on adjacent teeth. Interproximally, it should extend slightly lingual to the proximal contact with the adjacent teeth. If additional incisal translucency is required, some of the dentin porcelain on the lingual aspect of the incisal edge can also be carved away, and enamel porcelain can be placed in this area (Fig. 21–26). It is important to have some dentin porcelain extend to the incisal edge to prevent the formation of a definite line of demarcation in the fired crown at which the dentin ends and the enamel begins.

The mixed enamel porcelain is now added to the remoistened dentin until the oversized crown form is again achieved (Fig. 21–27A). The best way to uniformly remoisten porcelain is to spray the surface with a mist of distilled water in a refillable atomizer such as is designed for dispensing perfume. A moistened brush can also be touched to the dehydrated porcelain to transfer moisture.

The die and completed buildup must be removed from the working cast to permit the addition of more porcelain interproximally, so that the fired material possesses

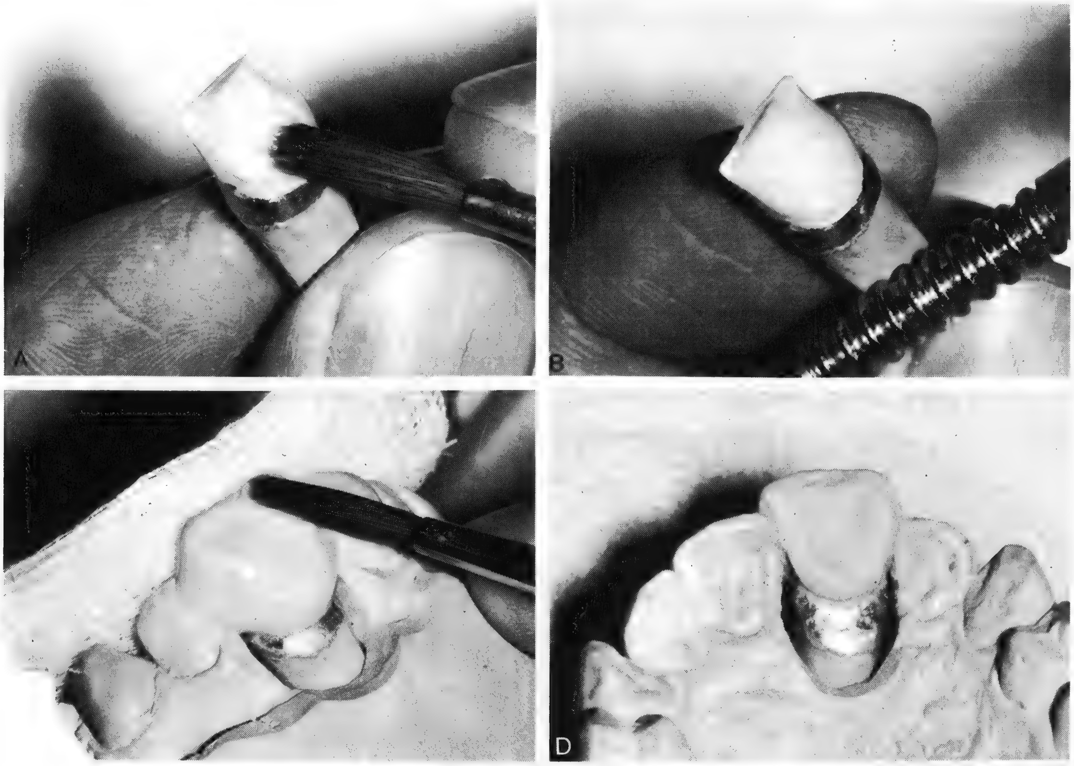


FIGURE 21–24 Dentin Porcelain Application

'celain being applied to facial surface.
'th serrated instrument to distribute porcelain.
'rking cast and bulk of dentin porcelain being applied. Absorbent gauze square is located

gually.

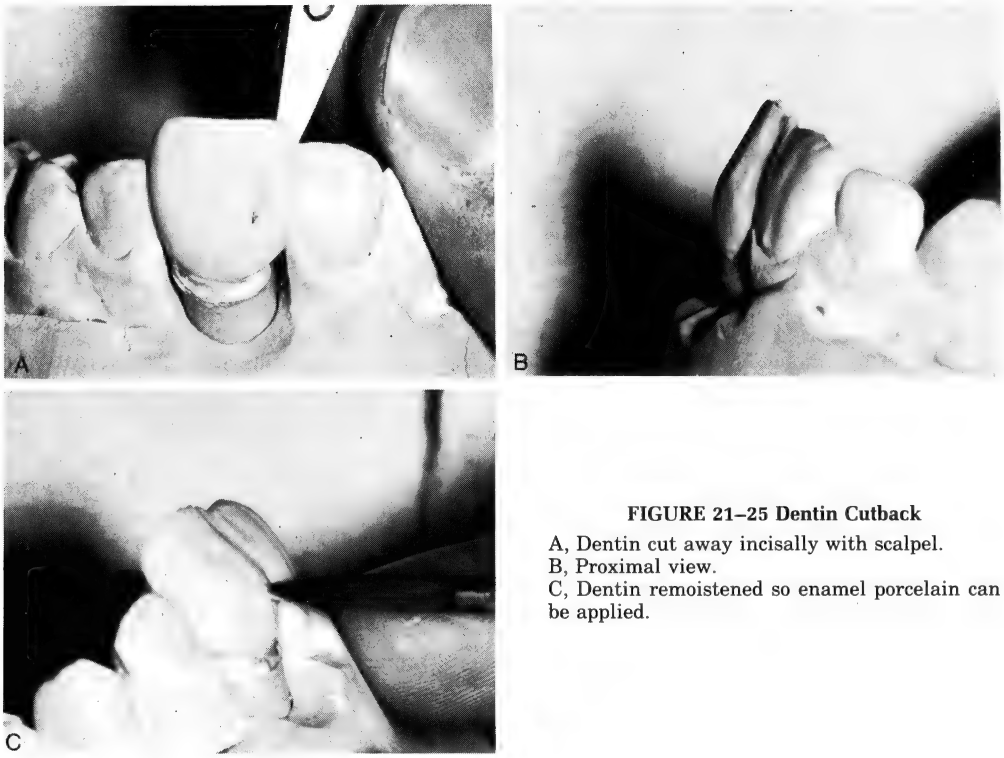


FIGURE 21–25 Dentin Cutback

A, Dentin cut away incisally with scalpel.
B, Proximal view.
C, Dentin remoistened so enamel porcelain can be applied.

adequate mesiodistal dimension for shaping. It is mandatory that excess porcelain cervical to the proximal contacts (which is locked into undercut areas) be carved away so removal does not fracture the applied porcelain.

The porcelain may again require remoistening. Then additional dentin porcelain is added on the cervical aspect of the proximal surfaces and enamel porcelain incisally (Fig. 21–27B, C). The most proximal portions of the buildup should be entirely formed of enamel porcelain so that normal interproximal translucency is reproduced.

Condensation is accomplished as usual by tapping the die with a metal instrument while holding absorbent material on the lingual surface to control excess moisture as it rises to the surface. The moisture is removed and the process repeated until the porcelain powders are densely packed.

If a mechanically formed cervical ditch is being used, it is established at this time between the porcelain buildup and the platinum foil. It is advantageous to keep the cervical ditch as small as possible so that only a minimal amount of porcelain is required to fill in the ditch. In this way, there is a better chance of establishing the desired form with only one additional application and firing of porcelain. Also, the porcelain that fills the ditch adheres to the foil matrix at firing. If the bulk of

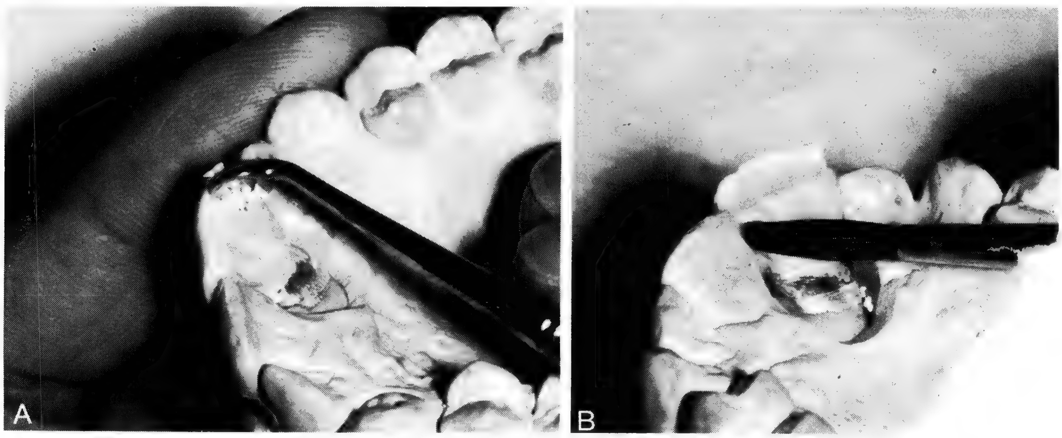


FIGURE 21–26 Cutback for Increased Incisal Translucency

A, Dentin carved away on lingual aspect of incisal edge.
B, Dentin remoistened.

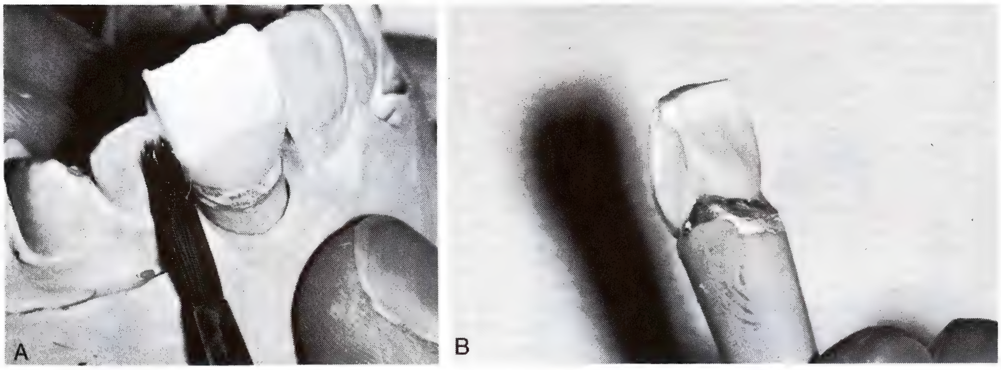


FIGURE 21–27 Enamel Porcelain Application

A, Enamel applied facially.
B, Die removed from cast shows depression at proximal contact.
C, Porcelain added proximally.

porcelain in the ditch is small, the amount of overall firing shrinkage is reduced, and consequently there is insignificant distortion of the platinum foil at the shoulder margin.

Prior to firing, a moistened brush is used to clean any remaining porcelain particles on the margin or apron cervical to the margin. If porcelain is left attached to the matrix, it will fuse in position and interfere with subsequent readaptation procedures.

The completed buildup is placed on a firing tray in front of the open muffle of the furnace for a drying period of 20 minutes (Fig. 21–28A). It is then fired in accordance with the manufacturer's instructions (Fig. 21–28B).

The fired restoration is returned to the silver-plated die, and the proximal contacts are adjusted so that the restoration and die are fully seated in the working cast (Fig. 21–29). There should be a slight excess of porcelain in all areas except at the cervical ditch. If other deficient areas of porcelain are observed, additional porcelain can be added in conjunction with filling in of the ditch.

The matrix is reburnished over the shoulder of the die (Fig. 21–30). A blunt metal instrument such as a DPT 6 is placed into the ditched area, and the foil is burnished against the silver-plated die.

The ditched area is moistened with distilled water and slightly overfilled with dentin porcelain. The porcelain is extended only slightly cervically to the finishing line. Excessive extension of the porcelain down the apron can result in too great a bulk in that area so that the firing shrinkage of the newly added porcelain occurs in a cervical direction. This situation may produce a

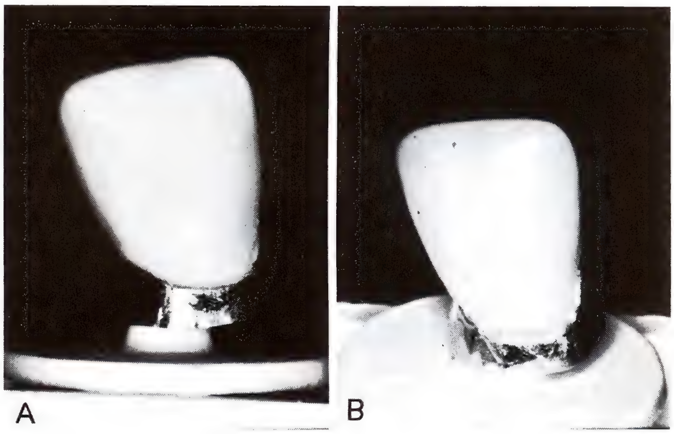


FIGURE 21–28 Initial Dentin and Enamel Firing

A, Porcelain dried.
B, Porcelain fired.

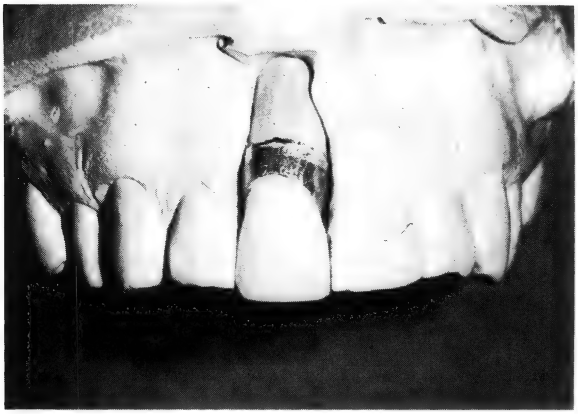


FIGURE 21–29 Restoration adjusted proximally to allow complete seating on working cast.

FIGURE 21–31 Restoration fired with slight cervical excess.

crack between the porcelain just fired in the ditched area and the porcelain fired from the first bake. If such a crack occurs, it is difficult and often impossible to fill in the area with additional porcelain. If separation occurs, the preferred location is between the porcelain and the foil.

The porcelain addition in the ditched area is condensed, dried, and fired.

The desired oversized form of the restoration may be complete after this second firing, or a small crack may develop at the margin. If this occurs, the fused porcelain is moistened, the crack filled, and the final firing accomplished. The restoration should now be slightly oversized and have fused porcelain extending somewhat cervically to the finishing line (Fig. 21–31).

Shaping and Glazing

Some shaping can be accomplished by using the removable die working cast, but the final form and occlusal adjustments should be accomplished on the mounted working cast because of its accuracy and the reproduction of soft tissue contours. However, the restoration cannot seat on the mounted working cast until the platinum foil and the porcelain that is cervical to the margin are eliminated. This involves marginating the crown, which is the step that determines the accuracy of fit of the final restoration. This should be done *carefully* and with the proper handling of the instrumentation to achieve optimal accuracy of fit and contour.

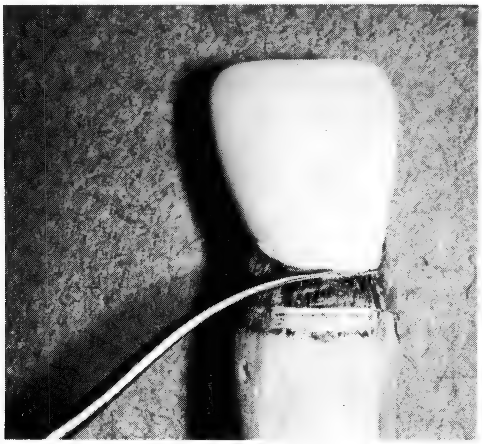


FIGURE 21–30 DPT 6 instrument used to reburnish foil over margin.

The excess porcelain that is cervical to the finishing line is removed by grinding with a Busch Silent Stone* and a diamond disc.† The excess porcelain gets thinner as the grinding progresses, and the matrix becomes more readily visible through the porcelain. Thus, the exact location of the margin can be determined visually (Fig. 21–32). The excess porcelain is initially removed more rapidly with the Busch Silent Stone, and the final margination is completed with the diamond disc. The direction of rotation for the disc as it contacts the porcelain should be from the margin toward the incisal edge. Grinding of porcelain with the disc rotating toward the margin can result in chipping of the porcelain at the margin of the restoration. A sharp explorer is used to evaluate the reduction process and achieve a well-fitting smooth margin. When the excess cervical porcelain is eliminated, the apron of platinum foil is cut away with scissors (Fig. 21–33).

At this point, the restoration can be seated on the die (Fig. 21–33) and the mounted working cast. The proximal contacts are adjusted to allow complete seating on the working cast. Another possible source of incomplete seating is contact of the cervical porcelain against the gingival tissue area of the cast. Such a fit is indicative of clinical soft tissue impingement that is not acceptable, requiring correction of the cervical contours of the restoration.

When the restoration is fully seated on the cast, the occlusion is adjusted, the final shape is established, and the surface characterization is completed.

The restoration is next tried on the tooth clinically. Any needed adjustments are made to enhance the shape and to perfect the occlusion.

Many porcelain jacket crowns produced in the laboratory are returned to the dentist in a glazed and completed condition with the platinum foil removed. Any adjustments require grinding and breaking of the glaze. An unglazed surface often is not acceptable es-

*Busch Silent Stone, Pfingst and Company, South Plainfield, NJ 07080.

†Horico 86X diamond disc, Pfingst and Company, South Plainfield, NJ 07080.

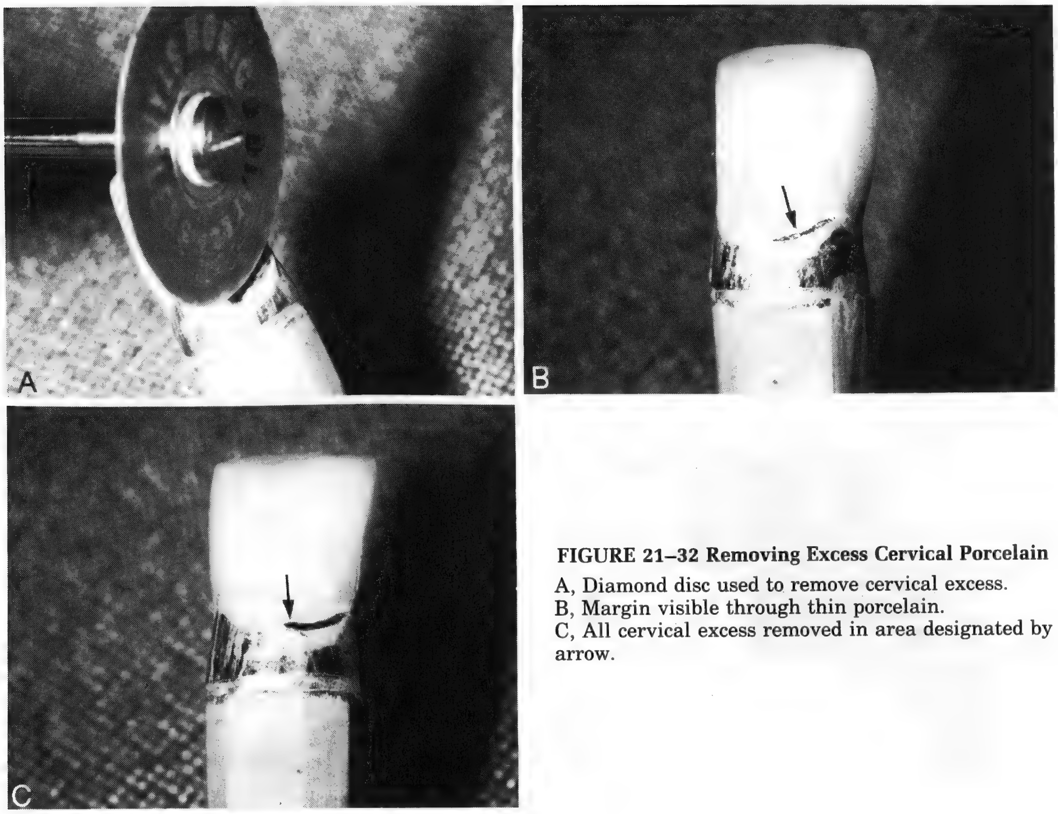


FIGURE 21–32 Removing Excess Cervical Porcelain
A, Diamond disc used to remove cervical excess.
B, Margin visible through thin porcelain.
C, All cervical excess removed in area designated by arrow.

thetically or hygienically and should be reglazed. Without the platinum foil matrix extending to the margin, the dentin porcelain can become rounded during reglazing and reduce the marginal accuracy of the restoration. For this reason, the matrix should not be removed until after the restoration is trial-inserted so that subsequent firing necessitated by color and form adjustments does not cause marginal distortion.

Final color modifications are completed by placing surface stains on the porcelain. The staining process can be completed in conjunction with the glazing process,

FIGURE 21–33 Cervical apron of foil removed and restoration transferred to stone die for evaluation of marginal fit.

since one firing cycle simultaneously fuses the stain and produces a glazed surface. The stains can also be applied and fired over a glazed surface. (The reader should see Chapter 25 for details regarding surface staining.)

Matrix Removal and Cementation

The platinum foil is removed from the restoration after all adjustments have been completed and the restoration has been glazed. A recommended method of removal is to use a new number 11 scalpel blade and to first lift the platinum foil free from the porcelain at the margin (Fig. 21–34A). The foil can be worked free from the axial walls of the restoration and gathered together in the center of the crown by a pair of cotton pliers (Fig. 21–34B). This procedure leaves only the incisal aspect of the platinum foil attached to the porcelain. A faciolingual rocking motion gradually loosens the matrix so it can be removed in one piece (Fig. 21–34C). Attempts to dislodge the matrix by pulling cervically instead of faciolingually can lead to tearing of the matrix, leaving remnants of foil adhering to the incisal portion of the restoration. These remnants can be very difficult to remove because of limited access and difficulty in obtaining a grasp on a small fragment.

After matrix removal is complete, the restoration is trial-seated on the stone die (Fig. 21–35).

One of the major esthetic advantages of a jacket crown is that it can allow the color of the prepared tooth to pass through the restoration and enhance the final esthetics. This process is possible when the normal core thickness is used facially and is advantageous when the

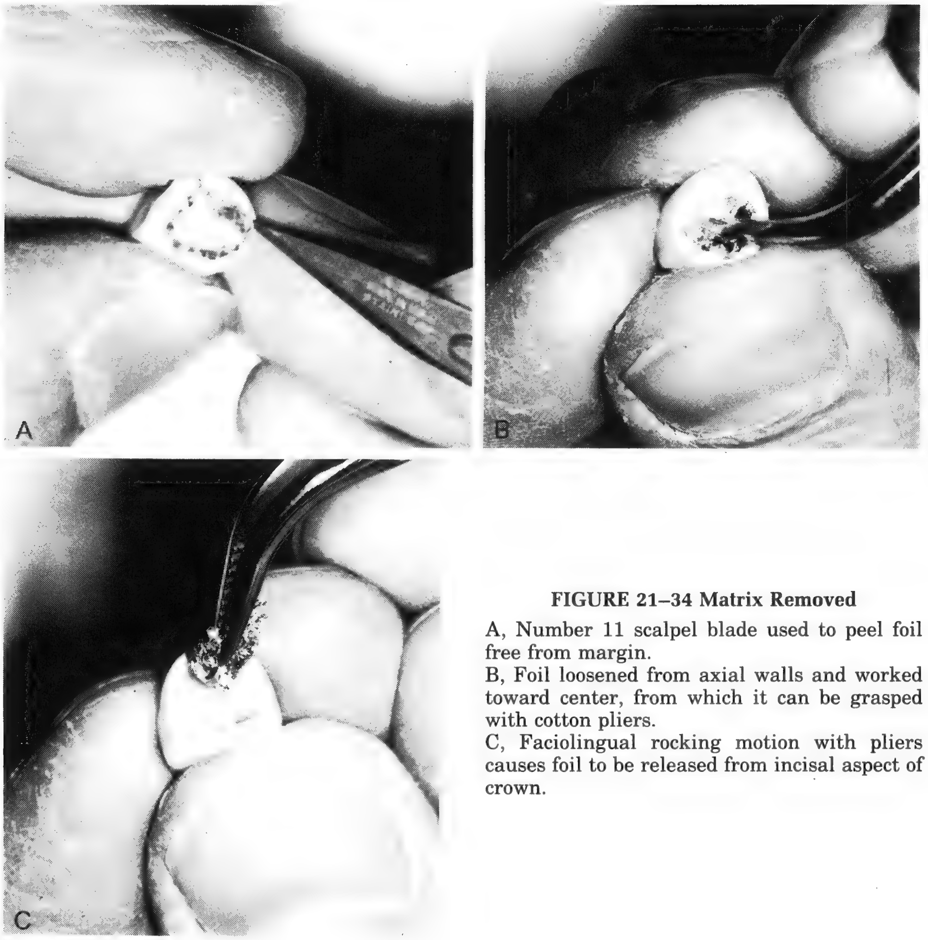


FIGURE 21–34 Matrix Removed

A, Number 11 scalpel blade used to peel foil free from margin.
B, Foil loosened from axial walls and worked toward center, from which it can be grasped with cotton pliers.
C, Faciolingual rocking motion with pliers causes foil to be released from incisal aspect of crown.

prepared tooth is not discolored. The esthetic enhancement is facilitated by the use of a translucent cement. Zinc silicophosphate cement is particularly well suited for this procedure, owing to its translucent nature, although glass ionomer and zinc phosphate cements are also used. Silicophosphate cement offers anticariogenic properties derived from its fluoride content and possesses low solubility in vivo, as does glass ionomer cement.

Silicophosphate cement is available in different colors, and it is possible to accomplish slight alterations in the color of the restoration at cementation. A trial mix of the proposed cement color can be made by mixing the powder with glycerine instead of the proper liquid. This mix does not set, and the restoration can be trial-seated on the prepared tooth for evaluation of the color change. Once the final decision is made, the trial mix can be dissolved by water and the final mixture made with the correct liquid. (The manipulation and properties of silicophospate cement were discussed in Chapter 17.) After complete setting, the excess cement is removed, and the area is cleansed (Fig. 21–1).

TWIN FOIL RESTORATIONS

This restoration contains a platinum foil matrix bonded to the porcelain and is therefore technically not an all-ceramic restoration. However, this restoration is discussed here, since a jacket crown preparation is used and many of the laboratory procedures are similar to those for a conventional porcelain jacket crown. The fabrication technique uses two matrices (one adapted over the other) (Fig. 21–36) and has become known as the *twin foil technique*. It was developed to strengthen the jacket crown by chemically bonding a platinum foil matrix to the core porcelain. The bonding theoretically would reduce the porosity occurring at the foil-core interface and thus increase the strength of the final restoration.

A number of experienced clinicians have indicated good results with a low incidence of clinical fracture. However, laboratory tests comparing the strength of these restorations with the strength of conventional jacket crowns have not found the former to be stronger.

The fabrication technique involves the usual adaptation of a platinum foil matrix (known as the inner matrix). A second matrix (the outer matrix) is adapted over the first matrix and cut so that the apron and the foil covering the shoulder are removed (Fig. 21–36).

The outer matrix is air-abraded (Fig. 21–37A), cleaned, and tin-plated using a special instrument* (Fig. 21–37B, C). It is heated so the tin oxidizes (Fig. 21–

*Multiplater, Unitek Corporation, Monrovia, CA 91016.

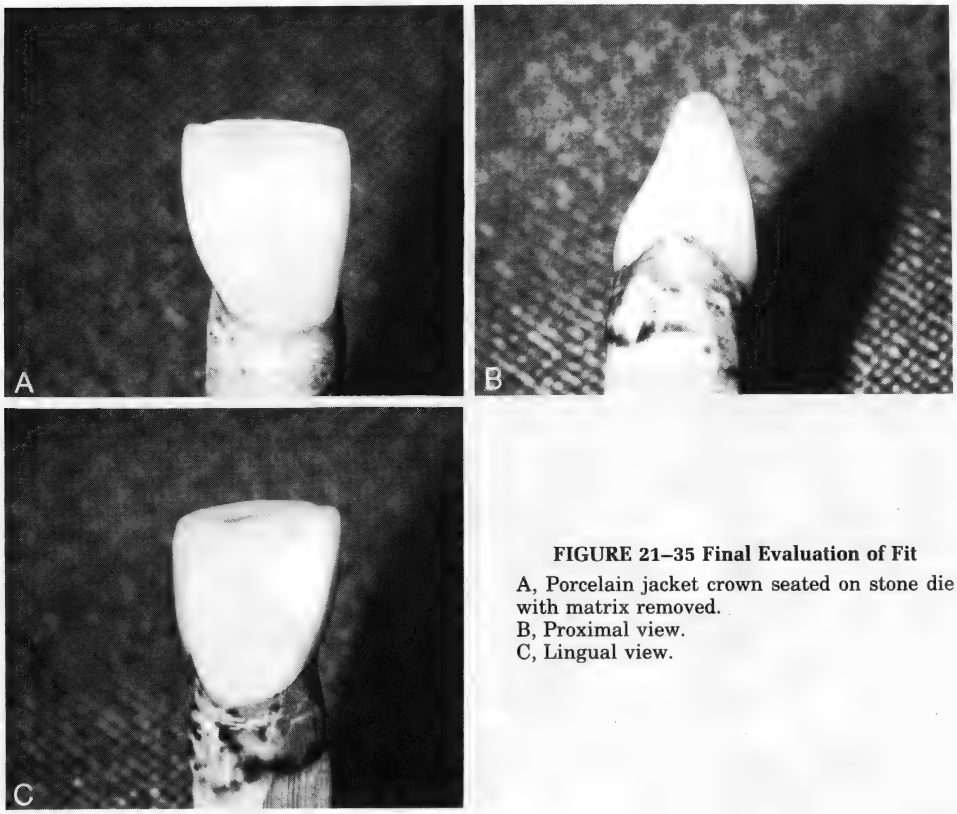


FIGURE 21–35 Final Evaluation of Fit

A, Porcelain jacket crown seated on stone die with matrix removed.
B, Proximal view.
C, Lingual view.

37D) to produce a chemical bond with the special core porcelain developed for this restoration. Next, a core porcelain is fired and bonded to the oxidized matrix (Fig. 21–37E), and dentin and enamel porcelains are applied (Fig. 21–37F). The restoration is glazed and the inner foil matrix removed while the outer bonded matrix is retained inside the crown. The complete restoration thus has no foil covering the shoulder but has the outer matrix bonded to the porcelain (Fig. 21–37G).

The presence of the bonded foil matrix interferes with the diffusion of light. Thus, while the restoration is considerably more esthetic than a metal-ceramic restoration, it is less esthetic than the conventional aluminous porcelain jacket crowns. The marginal adaptation of twin foil restorations is as good as that of conventional aluminous porcelain jacket crowns, whereas the internal adaptation is somewhat inferior (Fig. 21–38).

BONDED SINGLE FOIL RESTORATIONS

The single foil technique utilizes only one matrix, which is bonded to the core porcelain using the previously described procedures. Restorations are produced that show improved internal adaptation (Fig. 21–39)

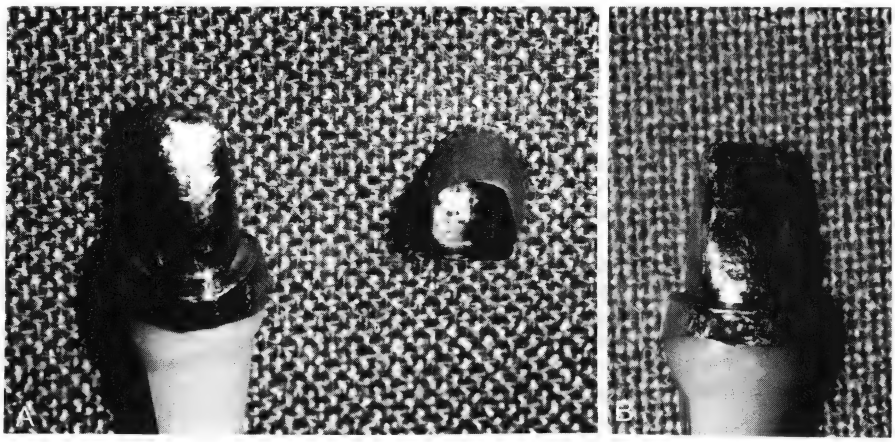


FIGURE 21–36 Twin Foil Matrices

A, The inner matrix is seated on the die. Note that the outer matrix has been trimmed so it does not cover the shoulder. Also, the incisal portion of the matrix has been cut away to allow light to pass through the incisal edge of the restoration.
B, Outer matrix seated over inner matrix.

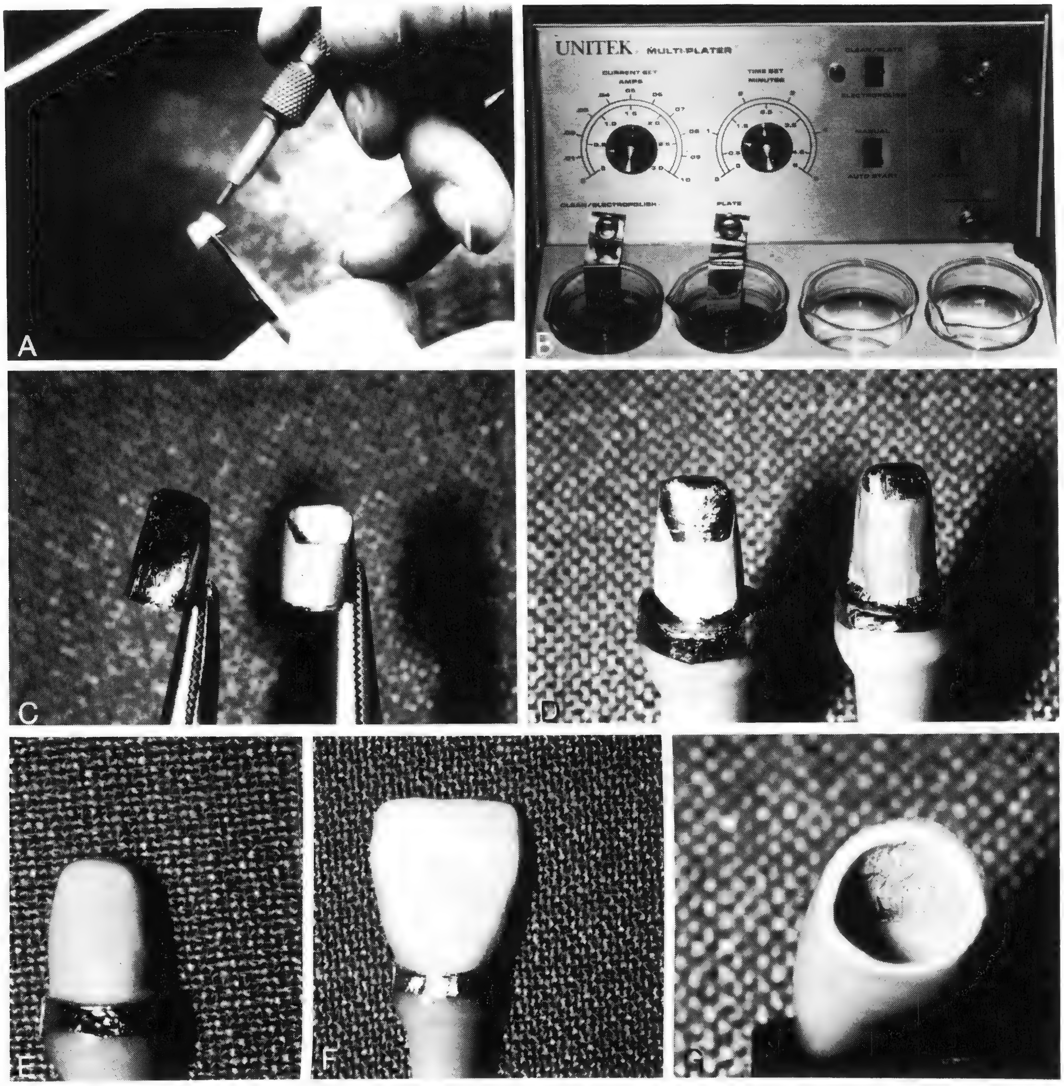


FIGURE 21–37 Plating and Porcelain Application

A, Air-abrading the foil matrix.
B, Plating instrument.
C, Left, matrix prior to air-abrasion and plating. Right, plated matrix.
D, Oxidized matrices.
E, Core porcelain fired.
F, Dentin and enamel porcelain applied.
G, Internal view of completed restoration showing matrix bonded to core porcelain.

and slightly greater strength when compared with the twin foil restoration.

The technique involves adapting only one matrix in the usual manner with a cervical apron. A piece of rubber dam is punched and stretched over the adapted matrix so that it covers the shoulder and matrix apron but not the axial walls. The matrix is air-abraded with aluminous oxide as described previously, except that the abrasive does not affect the shoulder or apron because of the rubber covering (Fig. 21–40A). When the matrix is plated, tin adheres only to the axial walls and not to the shoulder or apron, since the plating process only works properly on matrix surfaces that have been air-abraded (Fig. 21–40B). The restoration is fabricated as usual, shaped, and glazed. A sharp scalpel is used to cut the single foil at the point at which the plating stops (Fig. 21–40C). The foil covering the shoulder can be removed, since it is not bonded to the core porcelain, whereas the remainder of the matrix remains firmly attached to the porcelain (Fig. 21–40D).

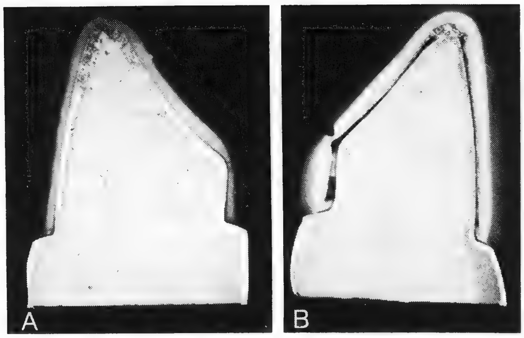


FIGURE 21–38

A, Cross section of conventional jacket crown.
B, Cross section of twin foil restoration showing similar marginal adaptation but poorer internal adaptation.

FIGURE 21–39 Cross section of bonded single foil restoration.

INJECTION MOLDED RESTORATIONS

A new technique* for fabricating all-ceramic restorations has recently been developed. This involves firing an injection-molded core, followed by application and firing of dentin and enamel porcelains in the usual manner.

The molding process requires the use of a hard die. An epoxy material has been developed that is reported not to shrink but actually to exhibit a controllable expansion with proper handling. The epoxy is mixed in a well-ventilated room and placed in a vacuum bell jar. Skin contact with the epoxy is avoided. It can then be painted into the impression with a brush. Only polyether, polysulfide, silicone, or poly (vinyl siloxane) impression materials are recommended for this process. Centrifuging can be used.

The epoxy must set for a minimum of 6 hours at room temperature and then be cured within 24 hours. The final cure is achieved by placing the cast in an oven at room temperature and heating it for 2 hours according to the manufacturer's specifications. A special buildup material is used to attach dowel pins, and a base is poured so that a removable die working cast can be formed in the usual manner.

*Cerestore, Ceramco, Inc., E. Windsor, NJ.

FIGURE 21–40 Bonded Single Foil Technique

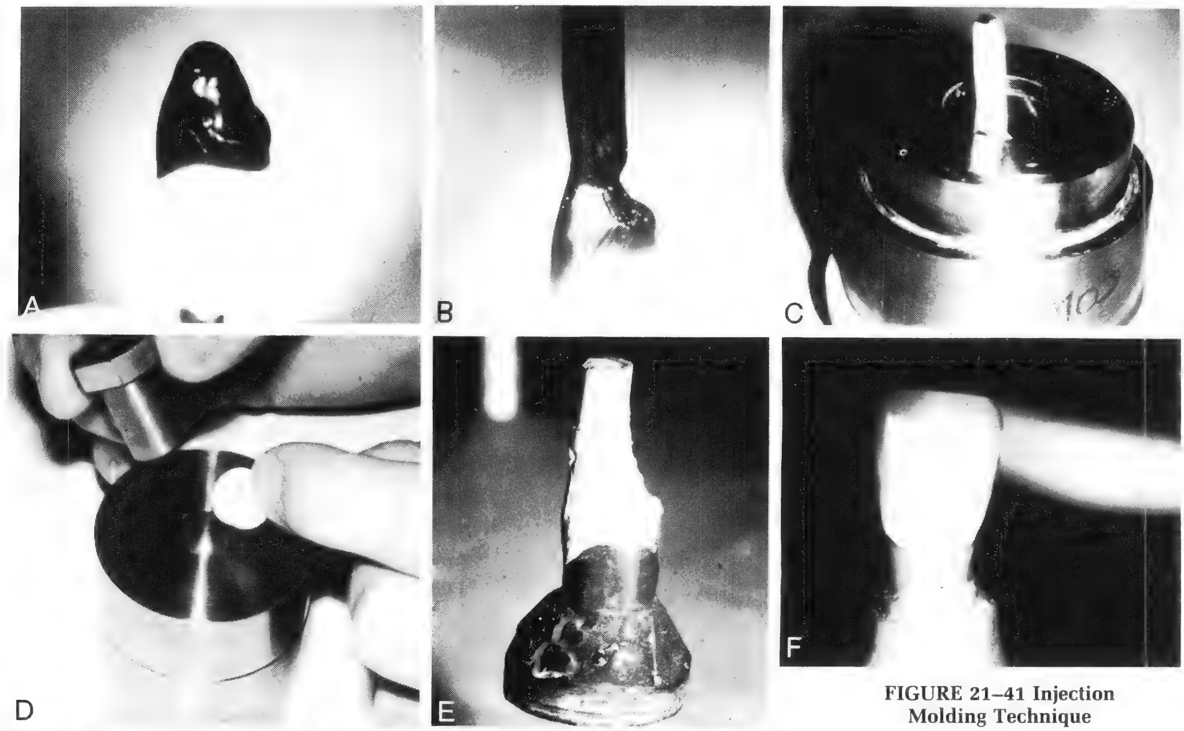
A, Shoulder of matrix covered by rubber dam material to prevent air abrasion.
B, Matrix plated except for shoulder area.
C, Foil being cut away from marginal area.
D, Internal surface of crown after shoulder portion of matrix has been removed.

The trimmed epoxy die is cleaned and coated with a release film that requires heat curing, and a die spacer is applied so as to create a 20- to 30-μm film thickness. The die is again heated to effect a cure.

A wax pattern is formed that possesses the usual coping form developed for full porcelain coverage metal-ceramic restorations (Fig. 21–41A). A minimal anterior wax pattern thickness of 0.5 mm must be maintained. Posteriorly, 0.8 mm is required. The lingual wax band should be 4.0 mm high occlusocervically. A larger than normal wax sprue former (6- to 8-gauge and 0.5 inch long) is attached to the pattern (Fig. 21–41B), and a layer of Type II die stone is applied over the pattern and sprue former (Fig. 21–41C). The stone is allowed to set, and the assembly is invested in a special ring with plaster. The wax is then flushed out with boiling water and the ring heated to 180° C (357° F) for 40 minutes. Longer heating times are required when more than one flask is heated in the oven.

The coping porcelain is made in tablet form with different colors available depending on the porcelain shade. The tablets are a resin-ceramic composite. The heated flask is removed from the oven and oriented upright in the air press base. A porcelain tablet of the appropriate color is placed in the flask top (Fig. 21–41D), the unheated plunger is inserted over the tablet, and the injection molding process is actuated. This procedure should be completed in 15 seconds or less. The injected coping is left under pressure for 10 minutes. The flask is cooled, and the coping is divested (Fig. 21–41E). The sprue can be easily removed and the core shaped by conventional rotary instruments. Careful handling is required, since the ceramic material is fragile at this stage. A minimal facial core thickness of 0.5 mm should be maintained. The finalized core then is subjected to an 11-hour firing cycle with different temperatures and time intervals, reaching a maximum of approximately 1300° C (2372° F).

The fired coping is coated with a sealing agent and stained as needed. It is then refired in the oven. Dentin



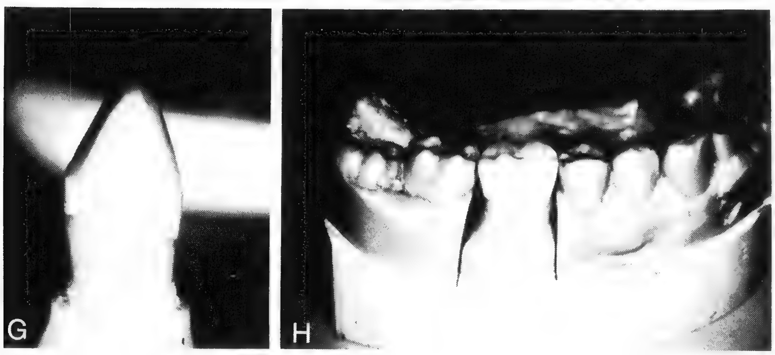


FIGURE 21–41 Injection Molding Technique

A, Wax coping for central incisor.
B, Large sprue former attached to pattern.
C, Thin layer of die stone painted over pattern and sprue former. The die and covered pattern have been placed in the metal investing ring. Plaster will be made to flow around the stone to complete the investing process.
D, Pellet of coping porcelain being placed into heated flask.
E, Devesting the coping.
F, Facial view of completed central incisor restoration.
G, Proximal view of completed central incisor restoration.
H, Facial view of completed mandibular molar restoration.

and enamel porcelains specifically designed for this restoration are applied and fired according to the manufacturer's recommendations. Shaping, surface staining, and glazing are handled as usual. The lingual cervical collar of coping material must be covered with a layer of glazing porcelain in order to achieve a smooth surface. Complete restorations are shown in Figure 21–41F–H.

This new technique of injection molding allows formation of an aluminous core by using a conventional wax pattern instead of the more technically demanding process of adapting a platinum foil matrix and hand building the porcelain, as is required for aluminous porcelain jacket crowns.

FIGURE 21–43 Occlusal view of maxillary molar restoration.

CENTRIFUGALLY CAST RESTORATIONS

Another new all-ceramic restoration* is fabricated by centrifugally casting the entire restoration form in a refractory mold developed from a wax pattern in the conventional manner. The procedure does not require special die materials, hand building of porcelain powders, or extensive grinding to develop the final shape. Detailed surface anatomy such as occlusal morphology can be carved into the readily alterable wax pattern.

The laboratory technique involves formation of a full contour wax pattern to which a larger than normal wax sprue former is attached. The pattern is invested in a non–carbon-containing phosphate-bonded investment. The ring liner, handling procedures, and powder-liquid ratio allow for investment expansion comparable with those used with base metal alloys.

The casting ring is burned out, the glass-ceramic material is melted, and the glass is centrifugally cast into the investment mold. A special motor-driven casting machine is used to continue rotation for 6 minutes after the initial thrust produced by a conventional spring is lost. The pattern is carefully devested, since it must be fired to attain its proper strength. The material is transparent at this time (Fig. 21–42). In the as-cast state, the sprue can easily be severed and the area can be smoothed with conventional rotary instruments.

Next, the restoration must be subjected to a heating cycle to promote the formation of crystals and allow their growth to the desired 1- to 2-μm size. These crystals increase the strength of the material. The restoration is reinvested in gypsum investment so that the heating cycle does not cause distortion, since a 2 to 3 per cent shrinkage occurs. A special oven is used for the 11-hour heating cycle, which reaches a maximal temperature of 1075° C (1967° F) after 4 hours and then holds at that temperature for 6 hours. A 1-hour cool-down time is required. When the restoration is devested, it has a milky white appearance (Fig. 21–42).

*Dicor, Dentsply Int., York, PA.

FIGURE 21–42 Left, ceramic restoration as cast. Center, restoration after heat treatment. Right, restoration after shaping, staining, and glazing.

Finally, the desired color is established with specially developed surface stains that are applied and fired according to the manufacturer's instructions (Figs. 21–42 and 21–43).

Long-term clinical experience must be reported by a wide range of practitioners before the injection molded and centrifugally cast restorations can be compared with traditional porcelain jacket and metal-ceramic restorations on the basis of esthetics and longevity.

BONDED GOLD–PALLADIUM MATRIX RESTORATIONS

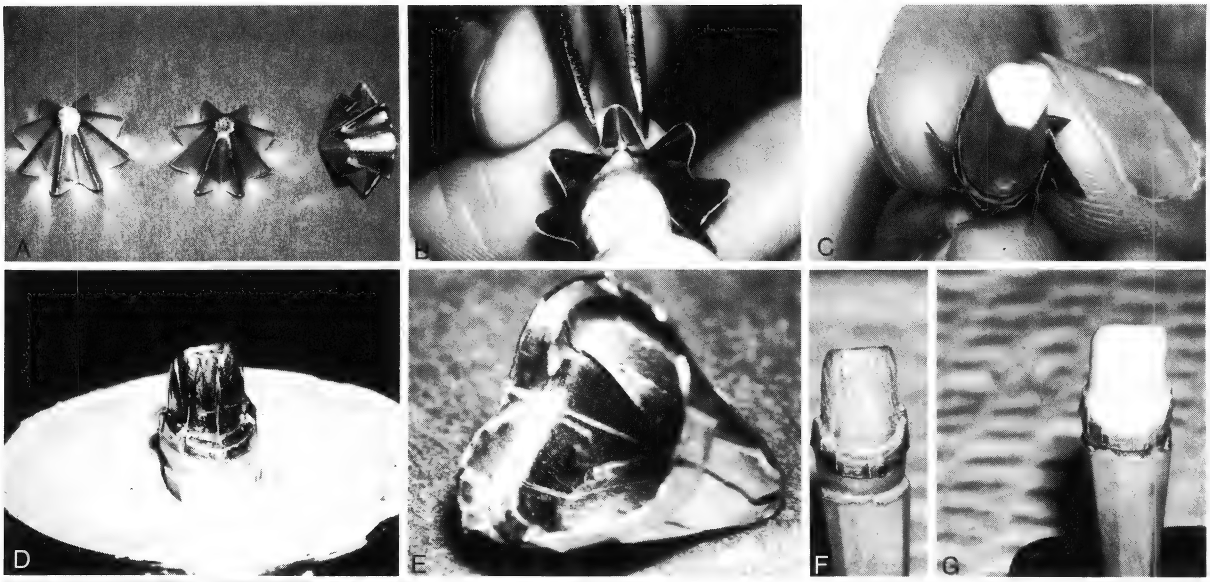
The most recently introduced porcelain restoration* contains a thin metallic matrix bonded to the overlying porcelain. It is therefore not a true all-ceramic restoration, but because of similarities of fabrication with the porcelain jacket crown, it is discussed in this chapter.

Fabrication involves the use of a matrix, which is either 51 or 58 μm thick, with the heavier-gauge material being used for posterior teeth. Matrices for anterior teeth are shown in Figure 21–44A. The matrix is composed of multiple thin layers of metal bonded together. There is a central layer of pure palladium that is covered internally and externally with a gold-palladium alloy. The outer gold-palladium layer is coated with 24-karat gold.

The uniquely shaped matrix is placed over an epoxy or plated metallic die and adapted by crimping the lateral projections together (Fig. 21–44B) and then folding them against the axial surface (Fig. 21–44C). Next, the matrix is burnished against the die, the cervical excess is trimmed away, and the final adaptation is achieved by swaging (Fig. 21–44D).

The adapted matrix is removed from the die and heated in a Bunsen burner flame until the gold flows and creates a soldered union between the matrix folds

*Renaissance, Williams Gold Manufacturing Company, Inc., Buffalo, NY 14214.



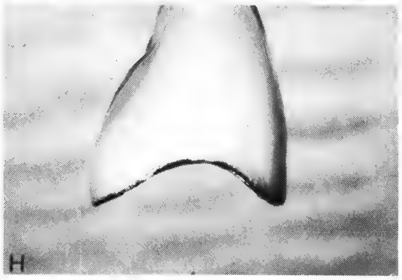


FIGURE 21–44

A, Anterior matrices.
B, Crimping instrument being used.
C, Lateral projections folded in one direction.
D, Matrix swaged.
E, Matrix soldered.
F, Bonding agent fired.
G, Opaque fired.
H, Completed restoration showing matrix at marginal area.

(Fig. 21–44E). A bonding agent is applied and fired (Fig. 21–44F), after which a thin layer of opaque porcelain is placed and fired (Fig. 21–44G). Dentin and enamel porcelains are built up and fired, and the marginal area is refined in a manner similar to that for a porcelain jacket crown. After final glazing, the metal remaining at the marginal area is smoothed with rubber polishing instruments (Fig. 21–44H). The restoration with an internally bonded foil is then ready for cementation.

22

The Metal-Ceramic Crown

The metal-ceramic crown is a full-coverage restoration that is generally less esthetic than an all-ceramic crown but that possesses greater strength and versatility. A cast metal framework covers the prepared tooth and provides the required strength, while porcelain is fused over visible portions of the metal to meet esthetic requirements (Fig. 22–1).

The lengthy discussion of the metal-ceramic crown presented herein is justifiable, since the metal-ceramic crown is by far the most commonly used restoration in fixed prosthodontics, in which it represents approximately 90 per cent of all restorations used.

To provide an acceptable esthetic result, the tooth must undergo greater facial, proximal, and incisal reduction than is required for an all-ceramic crown preparation. The extra reduction is needed to create space for the metal casting, an opaque porcelain that masks the metal, and overlying dentin and enamel porcelains of sufficient thickness to simulate natural tooth color and translucency.

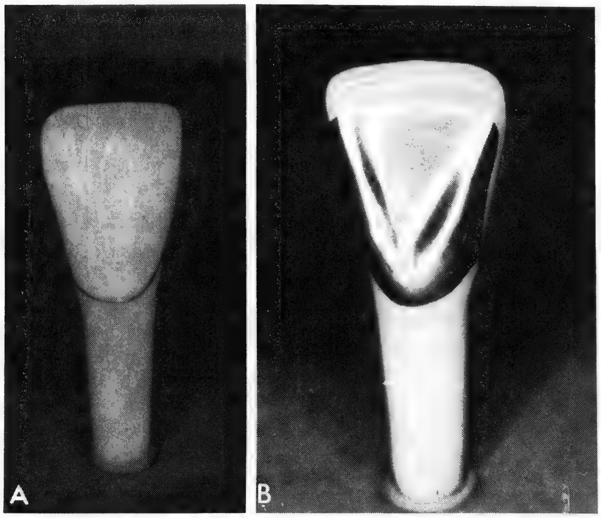


FIGURE 22–1

A, Facial view of central incisor metal-ceramic crown.
B, Lingual view of central incisor metal-ceramic crown showing metal framework.

The facial and proximal reduction should terminate in a shoulder so that a uniform thickness of porcelain can extend to the finish line. An esthetic thickness of porcelain is not required lingually, since this surface is less visible and is sometimes restored only with metal. Therefore, less lingual tooth reduction is necessary, and a chamfer finish line can be employed.

ANTERIOR METAL-CERAMIC TOOTH PREPARATIONS

Facial and Proximal Reduction

The facial surface should be reduced uniformly by a minimum of 1 mm to allow for development of adequate porcelain color. When large crowns and smaller pulps are encountered, a 1.5-mm facial reduction greatly enhances the esthetic result desired in the final restoration.

Small teeth or teeth with large pulps may not tolerate even 1 mm of reduction without irreversible pulpal damage. With this restricted depth of reduction, a less than optimal esthetic result can be anticipated, and there are no completely satisfactory solutions to this situation. Color-compensating techniques, such as internal modification of the porcelain color, are helpful but cannot completely overcome inadequate tooth reduction. Devitalizing these teeth permits additional reduction to be made but can produce visible coronal and root discoloration, which may not be completely masked by the restoration, thus also producing an esthetic problem.

Uniformity of facial reduction is essential to an esthetic result and is best accomplished by placing two or three depth cuts in the facial surface (Fig. 22–2). These cuts are placed slightly shallower than the desired final depth so that subsequent finishing achieves the desired depth without overreduction. The pulpal depth can best be gauged by using an instrument of the proper diameter and reducing the tooth until the instrument is within the external tooth contour.

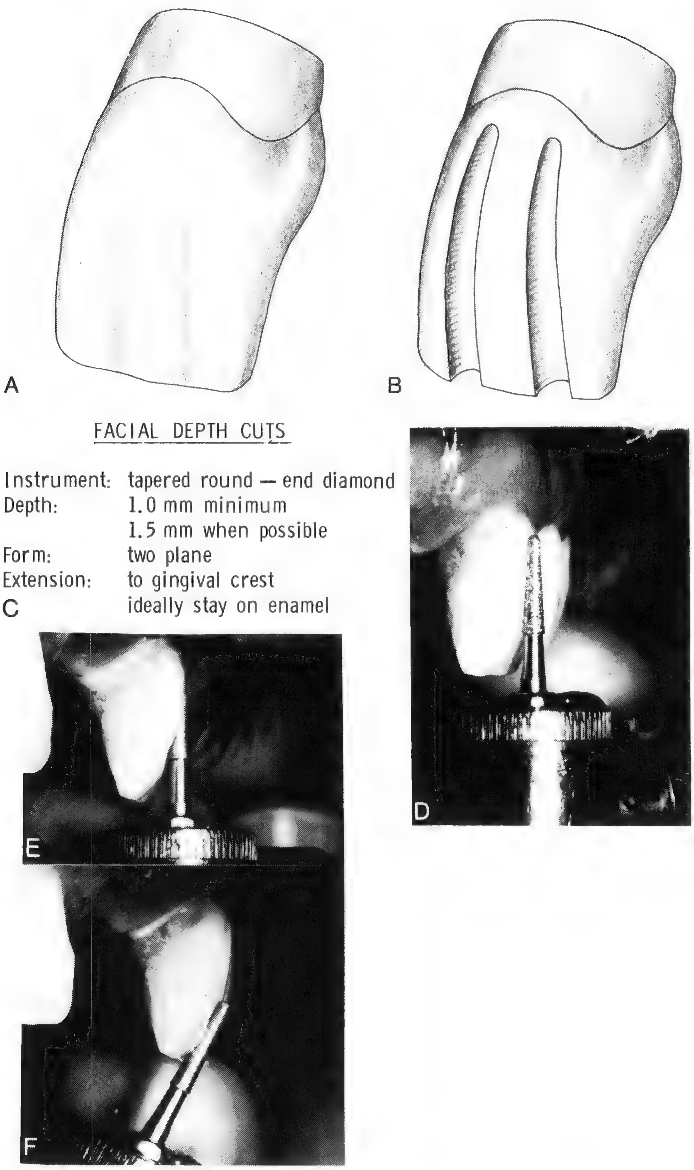


FIGURE 22–2

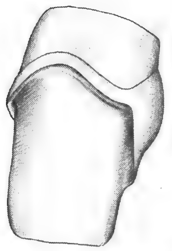
A, Maxillary central incisor prior to metal-ceramic preparation.
B, Facial depth cuts.
C, Procedures for producing facial depth cuts.
D, Tapered round-end diamond aligned with cervical tooth contour.
E, Reduction depth established cervically.
F, Instrument angle changed so depth cut follows contour of incisal portion of tooth.

The depth cuts are formed with either a coarse-grit* or medium-grit† tapered round-end diamond instrument while a copious water spray is used. When proximal space is limited, a smaller diamond instrument‡ can be used to prevent abrasion of adjacent teeth. A preliminary heavy chamfer finish line is formed, which subsequently is converted to a shoulder after all tooth surfaces have been reduced. The cuts should follow the facial tooth contour to produce different angulations to the cervical and incisal aspects of each depth cut. The cervical aspect of each depth cut is placed first and at this time should terminate slightly supragingivally to avoid soft tissue trauma from rotary instrumentation. The incisal portion of each depth cut is then completed following the angulation of the incisal one-half of the facial surface.

The tooth structure remaining between the depth cuts is removed, and the reduction is extended interproximally (Fig. 22–3), again creating a heavy supragingival chamfer finish line. The preparation should parallel the gingival contour to avoid cutting of the interdental papilla and extension of the initial finish line excessively deep into the gingival crevice.

The proximal reduction and heavy chamfer are extended to a point just lingual to the proximal contact area. An abrupt termination of the proximal reduction aids in evaluating whether proper lingual extension has been achieved, although some individuals prefer a gradual transition from shoulder to chamfer once the contact areas are reached. Greater lingual extension may be

*Two Striper 767.7C, Premier Dental Products Company, Philadelphia, PA 19107.
†Blu-White 1 DT, Teledyne Densco, Denver, CO 80207.
‡Blu-White ½ DT, Teledyne Densco, Denver, CO 80207.



A

FACIAL AND PROXIMAL REDUCTION

Instrument: tapered round—end diamond
Depth: 1.0 mm minimum
1.5 mm when possible
Form: two planes facially
follow gingival contour
Extension: lingual to proximal contact
to gingival crest
ideally stay on enamel

B

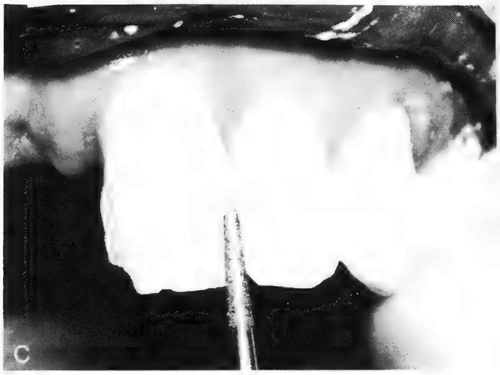


FIGURE 22–3

A, Facial and proximal reduction.
B, Procedures for producing facial and proximal reduction.
C, Facial surface reduced and distal proximal surface being reduced. With this tooth the preparation is to be terminated supragingivally and incisal to the cervical line.

necessary to provide additional porcelain thickness when highly translucent proximal surfaces are required.

For maximal retention, the reduced proximal surfaces should converge three to five degrees toward the incisal edge.

Incisal Reduction

The incisal edge is reduced a minimum of 2 mm using the tapered round-end diamond instrument and depth cuts to ensure adequate and uniform reduction (Fig. 22–4). This provides space for the metal casting and opaque porcelain and sufficient thickness of enamel porcelain to achieve the required translucency. Slightly greater reduction provides room for additional porcelain when more incisal translucency is needed. The limiting factor to incisal reduction is the length of the preparation that is required for retention of the restoration.

The incisal reduction is completed by using the depth cuts as a gauge (Fig. 22–5). The reduction should follow the mesiodistal and faciolingual inclinations of the incisal edge to ensure adequate and uniform reduction.

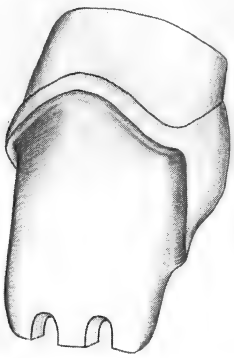
Lingual Reduction—Cingulum

The same tapered round-end diamond instrument is used to reduce the lingual surface cervical to the cingulum (Fig. 22–6). The instrument is aligned against the cervical aspect of the facial surface and then moved to the lingual surface in which a wall is formed that possesses the desired three to five degrees of taper relative to the cervical portion of the facial surface. A chamfer finish line, 0.3 to 0.5 mm in depth, is formed lingually and extended proximally to meet the existing heavy chamfer.

In order to establish a sufficiently retentive lingual wall, surgical recontouring of the gingiva may be needed when tissue covers a large portion of the lingual surface.

FIGURE 22–4

A, Incisal depth cuts.
B, Procedure for incisal depth cuts.
C, Two depth cuts placed.

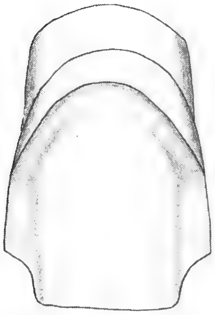


A

INCISAL DEPTH CUTS

Instrument: tapered round — end diamond
Depth: 2.0 mm

B



A

INCISAL REDUCTION

Instrument:	tapered round — end diamond
Depth:	2.0 mm
Form:	follow mesiodistal curvature
	follow faciolingual slope

B

C

FIGURE 22–5

A, Facial view of incisal reduction.
B, Procedures for incisal reduction.
C, Incisal reduction made using tapered diamond instrument.

Whenever possible, the finish line should be terminated on enamel.

Lingual Reduction—Occlusion

Optimally, reduction of the concave portion of the lingual surface should provide 1 mm of clearance with the opposing teeth in centric occlusion and throughout all eccentric mandibular movements (Fig. 22–7). Less reduction may be necessary when occlusal relationships and tooth thickness do not permit this amount of clearance. However, reductions below 0.5 mm do not allow sufficient thickness of metal for strength in the final restoration. If porcelain is to cover the lingual aspect of the casting, 1 mm of reduction must be achieved.

A wheel-shaped* or football-shaped diamond instrument† compatible with the concave lingual tooth form is recommended for this reduction.

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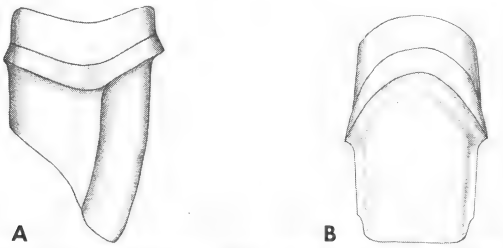
*Two Striper Number 860F, Premier Dental Products Company, Philadelphia, PA 19107.
†Number 368, Brasseler USA, Savannah, GA 31405.

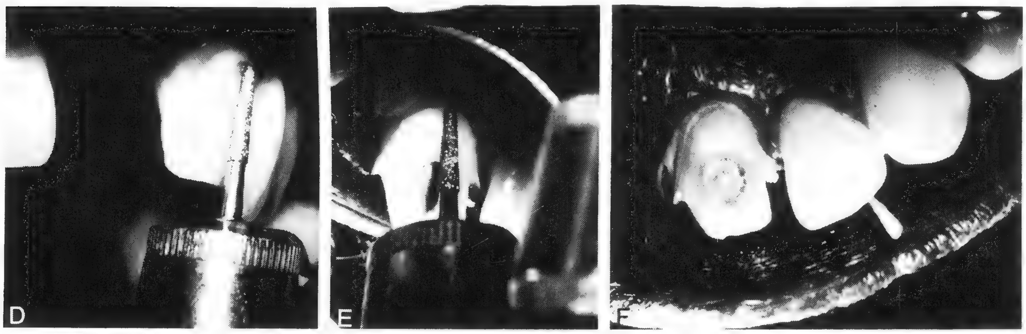


A B

LINGUAL REDUCTION - CINGULUM

Instrument:	tapered round — end diamond
Depth:	0.3 to 0.5 mm
Form:	follow gingival contour
Extension:	join shoulder proximally
	ideally stay supragingival
	ideally stay on enamel

C



D E F

FIGURE 22–6

A, Lingual reduction of cingulum as viewed proximally.
B, Lingual reduction of cingulum as viewed facially.
C, Procedures for lingual reduction of cingulum.
D, Tapered round-end diamond instrument aligned with cervical aspect of reduced facial surface.
E, Instrument carried to lingual surface while established alignment is maintained.
F, Lingual chamfer formed.

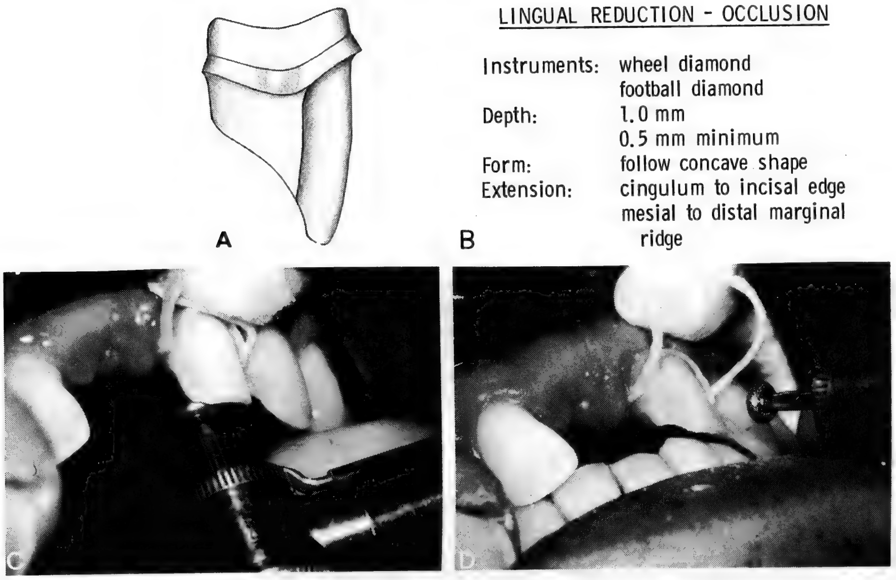


FIGURE 22–7

A, Lingual reduction for occlusion.
B, Procedures for lingual reduction for occlusion.
C, Wheel-shaped diamond instrument being used to reduce lingual surface.
D, Occlusal clearance being checked.

Types of Facial Finish Lines

Three types of facial finish lines have been used on metal-ceramic preparations: heavy chamfer, shoulder, and beveled shoulder. Each one has certain advantages and disadvantages.

The heavy chamfer is the easiest to form, but the metal framework is thinner cervically and undergoes more distortion during the heating and cooling cycles as porcelain is fused to the metal. In addition, the chamfer does not resist vertical forces very well. A thin layer of metal at this location may distort during seating of the restoration or during function, leading to porcelain failure. Also, overall porcelain thickness decreases as the margin is approached, and this causes the opaque porcelain to be closer to the external surface, which adversely influences cervical color and the appearance of depth.

Both the shoulder and the beveled shoulder finish line are harder to form but permit the metal framework to be more resistant to distortion during porcelain firing cycles. When a shoulder or beveled shoulder is used, good cervical porcelain color is also easier to obtain without overcontouring of the restoration.

In order to hide the metal at the finish line and establish good color incisal to the gingival crest, the beveled shoulder must be placed farther subgingivally than the shoulder. This relationship complicates the maintenance of periodontal health and makes tissue damage during tooth preparation more likely. Also, an accurate impression is more difficult to obtain.

Some individuals believe that it is difficult, or even impossible, to make castings that adequately fit a shoulder and that beveling the shoulder permits fabrication of better-fitting castings. The authors do not support this concept and believe that castings can be routinely fabricated to accurately fit either type of finish line.

If a heavy chamfer finish line is used, the preparation form is complete at this point. Only smoothing and rounding of line angles is necessary to finalize the preparation.

Shoulder Formation

When a facial shoulder finish line is used, the heavy chamfer is converted to a shoulder using a parallel-walled square-end 56 or 56L carbide bur (Fig. 22–8). The spiral flutes and the absence of crosscuts facilitate achieving a smooth surface. The shoulder width should be a minimum of 1 mm, with 1.5 mm being preferred when crown and pulp size permit.

If the finish line is to be terminated subgingivally, retraction cord is placed into the gingival crevice prior to formation of the shoulder. The cord provides about 1 mm of gingival displacement. The shoulder can be formed and extended to the level of the retraction cord without soft tissue trauma from rotary instrumentation. When the retraction cord is removed and the soft tissue returns to its usual position, the finish line is subgingivally located. Whenever possible, subgingival extension should be limited to 1 mm. Also, the finish line should be terminated on enamel and not extended onto the root surface, where less tooth structure is available for reduction.

During the shoulder formation, the carbide bur contacts the axial walls, and the final smoothness and taper are achieved. The flat cervical wall is smoothed using the tip of the carbide bur while care is taken not to contact the axial wall and create an undercut. Some

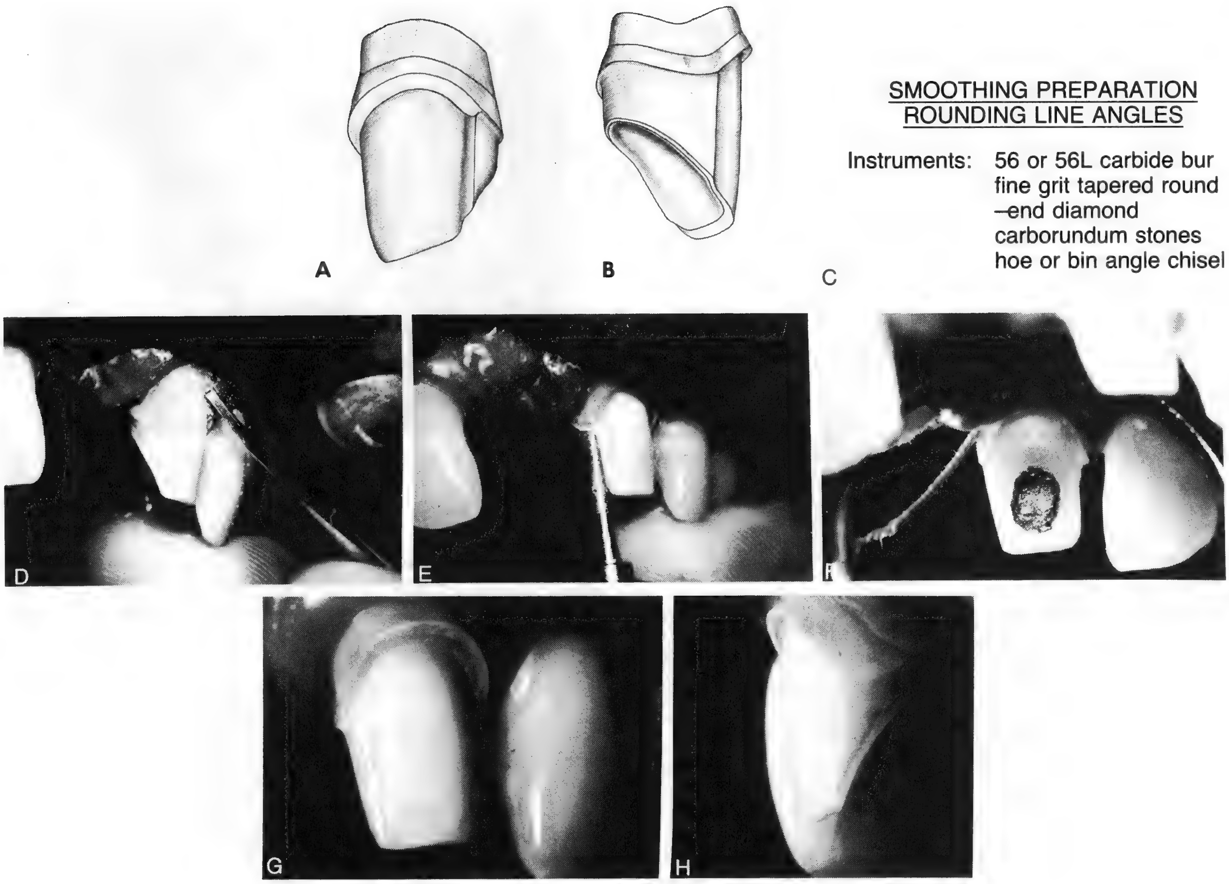


FIGURE 22–9

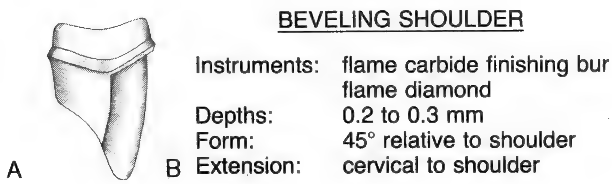
A, Facial view of completed metal-ceramic preparation.
B, Lingual view of completed metal-ceramic preparation.
C, Procedures for smoothing preparation and rounding line angles.
D, Smoothing the shoulder with a hoe.
E, Chamfer and lingual surface being smoothed with fine-grit tapered round-end diamond instrument.
F, Lingual view of completed preparation.
G, Facial view of completed preparation.
H, Proximal view of completed preparation.

with opposing teeth. Also, the depth of color is poor, with opaque porcelain often being visible.

Full-coverage porcelain restorations often produce dramatically greater amounts of wear when they oppose natural teeth or metallic restorations, particularly when contact is present in eccentric movements. Wear is not a significant problem when full-coverage porcelain restorations are opposed by other full-coverage porcelain restorations. When porcelain must contact enamel or metallic restorations, occlusion must be carefully controlled.

FIGURE 22–10

A, Shoulder beveled.
B, Procedures for beveling shoulder.



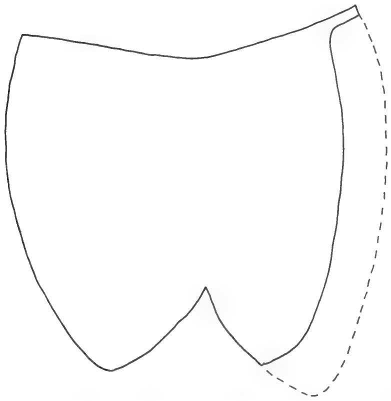


FIGURE 22–11 Metal-ceramic restoration for maxillary premolar with facial veneer of porcelain as indicated by broken line.

FIGURE 22–13 Metal-ceramic preparation for facially veneered restoration completed on maxillary second premolar.

WAX PATTERN FORMATION

Many metal-ceramic castings are made from wax patterns that never possessed the final dimensions of the restoration. This procedure is followed because development of full crown form in wax requires more time, and a large portion of the wax subsequently must be cut away to make room for an adequate thickness of porcelain. However, important advantages are gained by the establishment of the full crown contour in wax.

One advantage is the accuracy with which the cervical area of the crown is reproduced, which is critical from a periodontal standpoint. This aspect of the wax pattern is more likely to be properly contoured if it is developed from a full contour pattern, whereas inaccuracy often results when the cervical form is developed in the absence of total tooth form.

A fully contoured pattern is also useful for diagnostic purposes when multiple anterior restorations are planned. The patterns can be formed over diagnostic preparations that are made on a mounted diagnostic cast. This provides information about the size of the restored teeth, their arrangement, and occlusion. Measurement of the thickness of the completed wax patterns identifies how much tooth reduction is necessary to achieve the desired restoration form. Also, the amount of remaining tooth structure aids in determining whether this amount of reduction can be biologically tolerated.

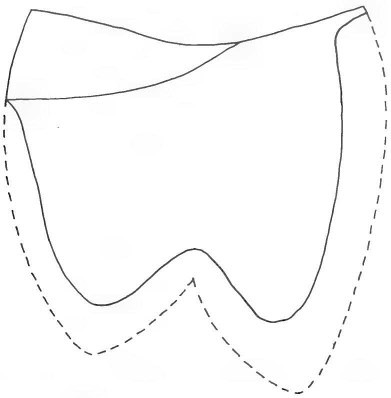


FIGURE 22–12 Metal-ceramic restoration for maxillary premolar with full porcelain coverage as indicated by broken line.

Even if a full contour wax pattern is not needed for diagnostic purposes, it is a valuable aid in determining the form of the final restoration. Decisions regarding the esthetic effects of various form changes and the best form to use are much easier to make when working with wax rather than with porcelain. When the final decision is made, a facial impression can be obtained with a putty silicone material, which is then poured in stone to obtain a cast that aids the subsequent porcelain shaping process. Such a record is particularly helpful in shaping porcelain for multiple anterior restorations or fixed partial dentures, since tooth size relationships and embrasure locations can be readily established according to a predetermined plan. When porcelain is shaped without a plan, time-consuming additions of new material are often needed to correct an undesirable form.

For posterior teeth, the previously described cone waxing technique (Chapter 13) is used to establish full-contour wax patterns. A similar cone waxing procedure can be used to facilitate the formation of morphologically accurate anterior full contour wax patterns.

ANTERIOR CONE WAXING

A thin wax pattern in the form of a coping is developed over the prepared tooth either by dipping or by wax application with an instrument. The thin coping is then placed on the working cast (Fig. 22–14A) so the following steps can be completed: formation of angle and cusp cones, proximal contours, incisal edge form, facial and lingual heights of contour, and completed wax pattern.

Angle and Cusp Cones

Wax cones are formed on the coping extending to the mesioincisal and distoincisal angles of the crown (Fig. 22–14B). For incisors, two proximoincisal cones are used, whereas a third cone extending to the cusp tip is

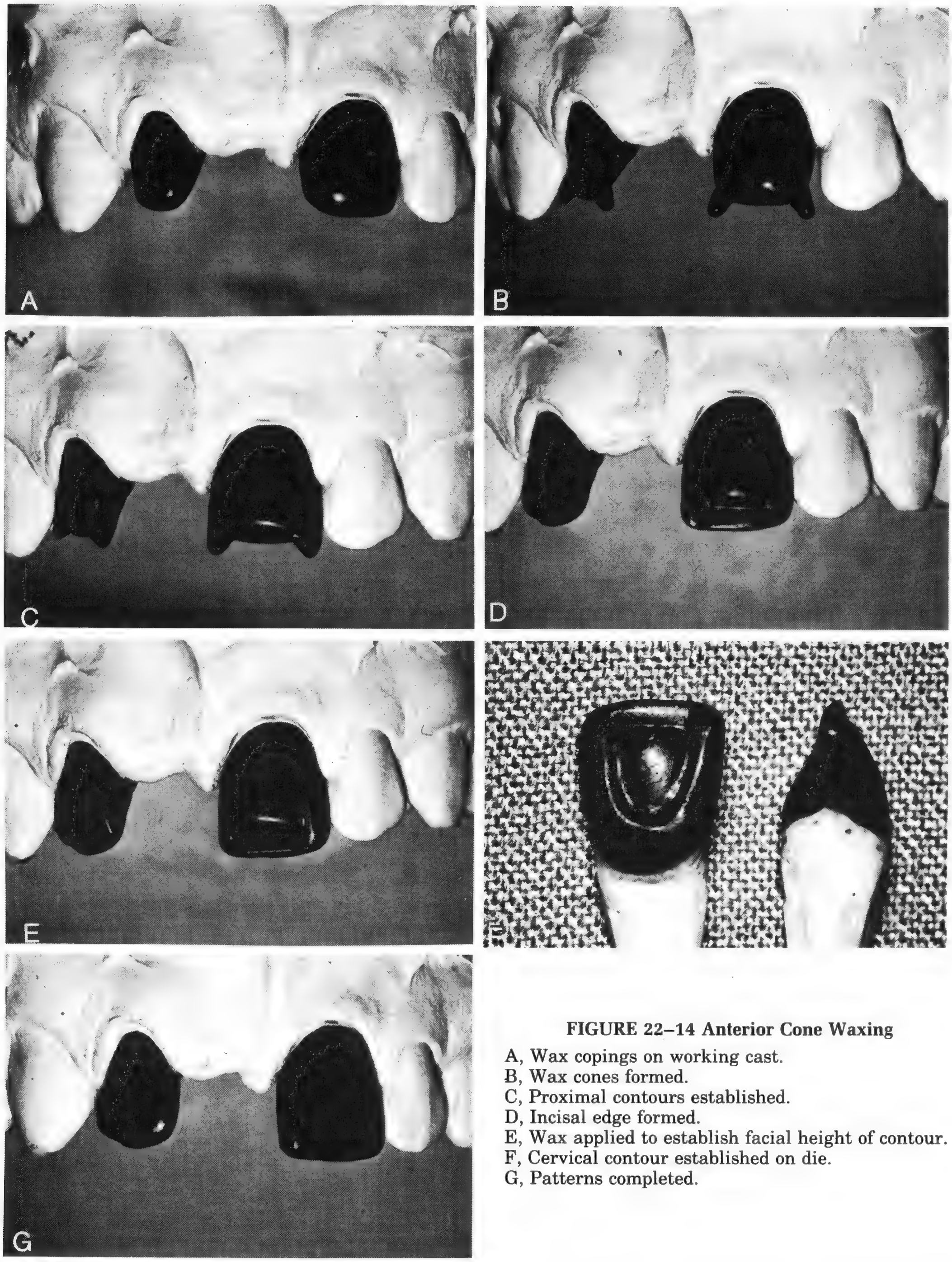


FIGURE 22–14 Anterior Cone Waxing

A, Wax copings on working cast.
B, Wax cones formed.
C, Proximal contours established.
D, Incisal edge formed.
E, Wax applied to establish facial height of contour.
F, Cervical contour established on die.
G, Patterns completed.

used on canines. The proximoincisal cones do not contact adjacent teeth, since proximal contacts are located cervically to the proximoincisal angles.

Proximal Contours

A rim of wax is placed between the margin of the wax pattern and each proximoincisal cone (Fig. 22–14C). While the wax is still soft, the pattern is seated on the working cast so that excess wax is displaced by adjacent teeth and the form can be evaluated. Additional wax is added or excessive material carved away as necessary. The location of the proximal contact area, the curvature of the proximal surface, and the cervical and incisal embrasure form are established at this stage. Cervical overcontouring must be avoided.

Incisal Edge Form

Another rim of wax is placed between the proximoincisal angle cones to establish the curvature and thickness of the incisal edge (Fig. 22–14D). The opposing cast is articulated with the wax pattern to ensure that an incisal edge form exists that is harmonious with the opposing teeth and eccentric occlusal relationships.

Facial and Lingual Heights of Contour

The facial height of contour is produced by applying wax in a looplike form extending from one proximoincisal angle to the other (Fig. 22–14E). The height of contour of the middle lobe is then created by making wax flow down the central portion of the facial surface. The lingual height of contour is formed by applying wax along the proximal surfaces to follow the marginal ridge and cingulum heights of contour.

Completed Wax Pattern

The wax pattern is returned to the die so that wax can be added between the height of contour and finish line to establish the cervical contour (Fig. 22–14F). Then the crown form is completed on the working cast by filling in the depressions left between and around the previous applications of wax (Fig. 22–14G).

Reducing the Wax Pattern for Veneering

Wax is removed from the full-contour wax pattern so that a form is developed that is suitable for veneering. Two distinctly different shapes are created, depending on whether the final restoration will possess full porcelain coverage or only a facial veneer of porcelain.

Anterior Wax Pattern Cutback for Facially Veneered Restorations

The full-contour wax pattern is completed, the occlusion is refined, and the centric occlusal contacts are marked on the pattern (Fig. 22–15A).

The wax pattern is reduced incisally until 0.3 to 0.5 mm of wax remains over the incisal edge of the die (Fig. 22–15B), thereby allowing sufficient space for translucency in the restoration. Either a number 4 PKT carving instrument or a number 11 scalpel blade can be used for this reduction.

The angle formed between the reduced incisal edge

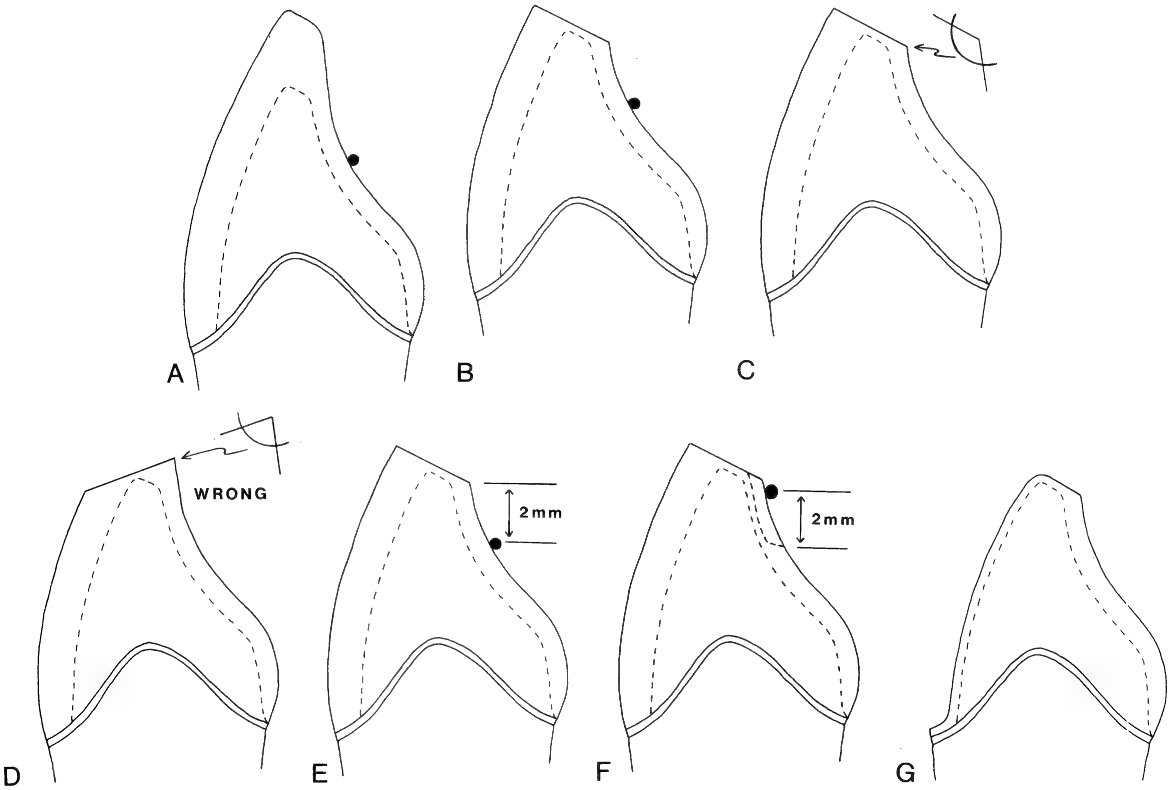


FIGURE 22–15 Wax Pattern Cutback

A, Wax pattern completed and occlusal contact indicated by dot.
B, Incisal edge reduced.
C, Obtuse angle formed between lingual surface and reduced incisal edge.
D, Improper angle formed.
E, Minimal distance between termination of cutback and occlusal contact.
F, Contact occurring close to junction requiring cervical extension of cutback and occlusal contact on porcelain.
G, Facial cutback.

and the remaining lingual surface deserves special consideration, as does the distance from the lingual termination of the cutback to the centric occlusal contacts.

The angle between the incisal edge and the intact lingual surface must be greater than 90 degrees (an obtuse angle) (Fig. 22–15C). If an acute angle is established, functional or parafunctional activity can produce forces capable of bending the metal at the metal-ceramic interface, thus resulting in porcelain fracture (Fig. 22–15D). An obtuse incisal angle provides greater bulk of metal at the metal-ceramic junction, and forces can be applied without causing significant deformation of the casting and resulting fracture of the porcelain.

The lingual termination of the incisal cutback must be located away from centric occlusal contacts. If contact occurs on or immediately next to the metal-ceramic interface, burnishing of the metal often occurs, and forces are placed on the porcelain that cause fracture. The metal-ceramic junction should be about 2 mm away from centric occlusal contacts (Fig. 22–15E). When the occlusal contact is located too close to the termination of the required incisal reduction, more of the lingual wax must be removed so that opposing tooth contact occurs on the porcelain instead of on the metal immediately adjacent to the junction (Fig. 22–15F). The cutback should extend at least 2 mm cervical to the centric occlusal contacts and could be extended even farther cervically.

Next, the facial aspect of the wax pattern is cut away, to leave 0.3 to 0.5 mm of wax over the facial surface (Fig. 22–15G). While the final metal casting is to be only 0.2 to 0.3 mm thick, it is advisable to have greater dimensions in the wax pattern and subsequently to reduce the thickness of the casting. This procedure is necessary to ensure that a complete casting is obtained and is particularly appropriate for inexperienced individuals who are just learning to melt and cast metal-ceramic alloys. Wax patterns that are only 0.2 mm thick facially often produce castings with perforations in the facial surface which make them unusable.

A cleoid-discoid* instrument or small spoon excavator is well suited for placing depth cuts into the wax so that uniform removal can be achieved. Although experienced individuals can evaluate pattern thickness by the amount of light that shows through the wax when it is held up to a bright light source, it is best to measure the facial thickness with a gauge.†

A wax collar, 0.3 to 0.5 mm thick, is left at the facial cervical aspect of the pattern to help prevent wax distortion as the pattern is removed from the die. This also provides the facial marginal thickness of metal necessary to adequately resist metal distortion during the porcelain firing cycles. Finally, the collar serves as a contour guide, helping to eliminate the overcontouring often seen around metal-ceramic crowns that do not have a cervical collar.

The proximal cutback is extended lingually to a point about 1 mm lingual to the proximal contact area. This allows development of proper interproximal shading and translucency in the final restoration. If large cervical embrasures are present, additional lingual extension of the proximal cutback is necessary to avoid interproximal display of metal.

The final step in the cutback involves smoothing and rounding of all surfaces to be veneered. Sharp angles or projections must be removed, since they create stress, which can cause porcelain fracture. Particular attention must be paid to rounding of the labioincisal line angle.

Posterior Wax Pattern Cutback for Facially Veneered Restorations

A similar cutback is used for posterior wax patterns (Fig. 22–16). The facial surface is reduced, and the same cervical collar size is established. The occlusal portion of the facial cutback is reduced to form an obtuse angle between the cutback surface and the unreduced occlusal surface. The metal-ceramic junction must also be kept about 2 mm from the centric occlusal contacts. When this is not possible, owing to the occlusal relationship with opposing teeth, the cutback must be extended lingually so occlusal contact occurs only on porcelain.

The wax pattern is reduced proximally so that no metal is visible in the final restoration. Since the distal surface of posterior teeth is often not visible, the cutback on the distal surface may not have to be extended as far lingually. All sharp areas on the veneering surface are rounded as usual.

Wax Pattern Cutback for Anterior and Posterior Full Porcelain Coverage Restorations

The wax pattern is reduced to provide space for porcelain on all surfaces (Fig. 22–17). The incisal or occlusal surface is reduced until a wax thickness of 0.3 to 0.5 mm is obtained. The proximal and lingual surfaces are then reduced to leave the same thickness of wax.

A cervical collar of wax is retained around the entire perimeter of the pattern to provide rigidity in the otherwise thin casting. The collar possesses the usual 0.3 to 0.5 mm of facial thickness, but proximally it is gradually increased until a thickness of 2 mm is achieved lingually. When a restoration is to be subjected to heavy occlusal forces, increasing the lingual collar height to 3 mm provides additional casting rigidity.

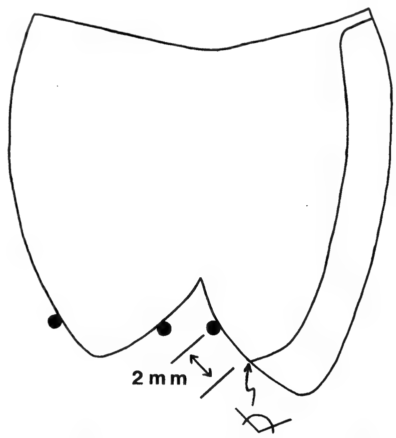


FIGURE 22–16 Wax pattern cutback for maxillary posterior tooth.

*Loma Linda GF32 instrument, American Dental Manufacturing Company, Missoula, MT 59801.

†Iwanson Wax Thickness Gauge, Pfingst and Company, Inc., New York, NY 07080.

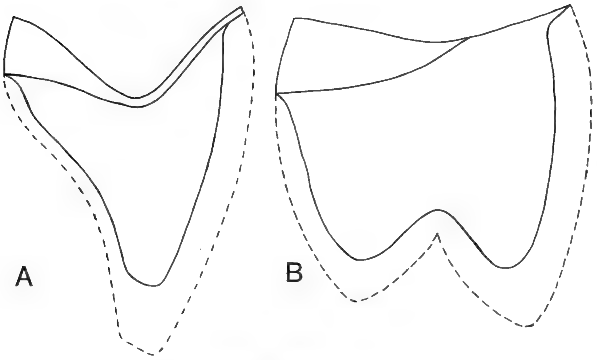


FIGURE 22–17
A,B, Cutback for full porcelain coverage.

A bead of wax can be applied over thinner wax surfaces so that molten alloy can reach all the areas of the mold to aid in the formation of a complete casting.

Readaptation and Sprue Former Attachment

The margin is readapted to the die and finished as usual. For facially veneered anterior wax patterns, a 5-mm length of 10-gauge round wax is used as the sprue former. This segment is attached to the center of the incisal edge (Fig. 22–18). It should be located and angled so that the molten alloy flows to both the facial and the lingual surfaces, with the incisal edge dividing the alloy as it enters the mold. The sprue former can be attached to the lingual surface, but this creates a greater chance of solidification of the molten alloy before it fills the entire thin facial area of the mold.

Sprue formers are attached to the thickest portion of posterior wax patterns for facially veneered castings. The sprue former should be angled so the molten alloy flows toward the thinner facial surface as it enters the mold.

Sprue formers for full porcelain coverage wax patterns are attached to the incisal edge of anterior patterns and to one of the cusps on posterior patterns. The sprue former is angled so that the molten alloy is dispersed evenly to all areas of the mold.

FIGURE 22–18
A,B, Sprue former attached.

Pattern Orientation in the Ring

The sprue former is attached to the crucible former as usual. The casting ring is oriented over the wax pattern so that thinner aspects of the pattern are positioned toward the trailing edge when the ring is placed into the casting machine (as discussed in Chapter 14).

PHOSPHATE-BONDED INVESTMENTS

Metal-ceramic alloys melt at higher temperatures [1149 to 1372° C (2100 to 2500° F)] than the conventional noble metal alloys used in fixed prosthodontics. Gypsum-bonded investments break down at these temperatures and liberate elements that contaminate the alloy. Phosphate-bonded investments withstand these higher temperatures and can be used with all types of metal-ceramic alloys. These materials may also be used to cast traditional alloys, and they are possibly more popular than the gypsum-bonded materials.

Composition

These investments, like the gypsum investments, consist of refractory fillers and a binder. The filler is silica, in the form of cristobalite or quartz, or a mixture of the two, and in a concentration of approximately 80 per cent. The filler provides refractoriness and a high thermal expansion. The particle size varies from submicron to that of a fine sand. The seemingly sandy feel does not necessarily relate to casting smoothness or affect the ease of removing the casting from the investment.

The binder consists of magnesium oxide and a phosphate that is acid in nature. Originally phosphoric acid was used, but monoammonium phosphate has replaced it, since the latter substance can be incorporated into the powdered investment. Use of phosphoric acid would be cumbersome, since most phosphate investments already utilize one liquid, with the powder being mixed with an aqueous colloidal silica suspension.

As noted, the newer gold-containing alloys and other alloys used in metal-ceramic restorations have higher melting temperatures than do traditional gold alloys. It follows that their contraction during solidification is also greater. This necessitates a greater expansion in the investment. Fortunately, the colloidal silica suspensions just mentioned became available in time for use with the phosphate investments.

In order to simplify the procedure and to facilitate shipping, since colloidal silica solutions freeze in cold weather, some phosphate investments have been produced in which water may be used as the gauging liquid.

Carbon is often added to the powder to help produce clean castings and to facilitate the "dig-out" of the casting. This addition is appropriate when the casting alloy is gold based, but there is disagreement regarding the effects of carbon in phosphate investments used for casting high–palladium-content or base metal alloys. It has been suggested that carbon embrittles the alloys, although the investment is heated to temperatures that burn out the carbon. The latest evidence indicates that palladium does not react with carbon at temperatures

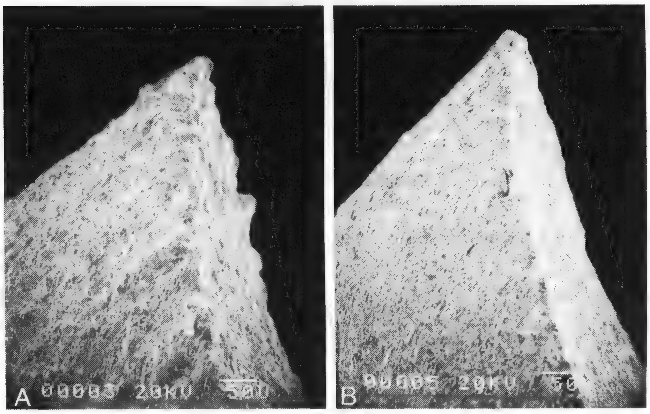


FIGURE 22–19

A, Scanning electron micrograph of platinum-gold-palladium alloy cast into carbon-containing phosphate-bonded investment.
B, Note the smoother surface obtained when the same alloy is cast into carbon-free phosphate-bonded investment.

below 1504° C (2740° F). Thus, if the casting temperature of a high–palladium-content alloy exceeds this critical point, a phosphate investment without carbon should be used. Also, under the same circumstances a carbon crucible should not be employed to melt the alloy. Generally, even gold alloys used with porcelain should not be premelted or fluxed on charcoal blocks because trace elements that provide high strength are in effect removed or reduced below the desired level.

There is some evidence to indicate that carbon-free phosphate-bonded investments yield castings that have smoother surfaces than those that contain carbon (Fig. 22–19).

Working and Setting Time

Unlike gypsum investments, phosphate investments are markedly affected by temperature. The warmer the mix, the faster it sets. The setting reaction itself gives off heat, and this further accelerates the rate of setting. Increased mixing time and mixing efficiency, as determined by the type of mixer and speed of mixing, result in a faster set and a greater rise in temperature. In general, the more efficient the mixing, the better is the casting in terms of smoothness and accuracy. The ideal technique is to mix as long as possible yet have just enough time for investing. Mechanical mixing under vacuum is preferred.

Another variable that has a considerable effect on the working and setting time is the liquid-powder ratio, which is often varied considerably, depending on user preference. An increase in the liquid-powder ratio increases the working time, which can be very short (2 minutes or less) when the investment is mixed at the manufacturer's recommended liquid-powder ratio and at high speed for the recommended time. This finding is especially true if the laboratory is warm and the liquid has not been chilled.

INVESTING PROCEDURES

The procedure varies somewhat from that used with gypsum-bonded investments. The wax pattern is coated with an appropriate cleansing and surface-tension–reducing agent as usual. For gold-platinum-palladium, gold-palladium, and high–palladium-content metal-ceramic alloys, the use of one thickness of ring liner, as in the technique used with conventional gold alloys, yields good results. For base metal alloys, more investment expansion is needed. The use of two ring liners increases the cushioning effect of the liner to allow more setting expansion of the investment.

In addition to ring lining procedures, the liquid-powder ratio must be adjusted to compensate for the expansion requirements of different metal-ceramic alloys and individual handling variables. No one liquid-powder ratio is suitable for all individuals and all alloys.

The liquid-powder ratio affects the setting expansion of the investment and thus the fit of the casting. Thicker mixes of investment (lower liquid-powder ratios) produce more setting expansion and thus a looser-fitting casting. When a phosphate-bonded investment that makes use of a special liquid is employed, another dimension is added. The use of a special liquid produces more investment setting expansion than does the same amount of water.

Setting expansion can thus be altered in two ways: (1) by varying the liquid-powder ratio and (2) by altering the special liquid-to-water ratio within the overall amount of liquid used. These two expansion controls are varied to produce an optimal result that compensates for individual handling characteristics and the type of alloy being used. Some liquid-powder ratios established through laboratory experimentation are presented in Table 22–1 as guidelines for establishing individual optimal ratios.

A technique for obtaining the best liquid-powder ratio can be developed in the following manner. The liquid-powder ratio is varied until adequate working time is achieved and a smooth casting surface is obtained. These two characteristics compete with each other, since a thin mix provides more working time but a rougher casting surface. However, after experimentation, a liquid-powder ratio can be established that allows sufficient working time and produces a smooth casting. If this ratio does not yield the optimal marginal fit, expansion can be manipulated by altering the overall liquid-powder ratio or by diluting the special liquid with water while maintaining the overall liquid level.

Phosphate-bonded investments are more viscous when mixed than are gypsum-bonded investments, and vacuum investing can lead to entrapment of bubbles in corners of the pattern. For this reason, vacuum mixing and hand investing is the technique of choice for invest-

TABLE 22–1. INVESTING AND BURNOUT VARIABLES RELATED TO TYPE OF ALLOY

Alloy Type	Investment	Number of Liners	Total Amount of Liquid (ml)	Amount of Special Liquid	Amount of Water	Burnout Temperature
Gold-platinum-palladium	Phosphate-bonded (carbon-containing)	1	11	9	2	704° C (1300° F)
Gold-palladium	Phosphate-bonded (carbon-containing)	1	11	9	2	760° C (1400° F)
High palladium	Phosphate-bonded (carbon-free)	1	8.5	4.5	4	816° C (1500° F)
Base metal	Phosphate-bonded (carbon-free)	2	8.5	8.5	0	871° C (1600° F)

ing metal-ceramic wax patterns. The liquid is placed into the vacuum mixing bowl first, followed by the powder. Hand mixing with a spatula is carried out until all the powder is incorporated into the liquid (Fig. 22–20A,B). The mixture is vacuum spatulated at the high speed for 15 to 30 seconds, the vacuum is released, and the mixture is vibrated for several seconds to accumulate the investment in the bottom of the bowl.

Excess wax pattern cleaner is removed by using compressed air and a small bead of investment picked up with a brush or metal instrument and brought into contact with an internal axial wall of the wax pattern. Vibrating the crucible former gently causes the investment to flow to the bottom of the pattern (Fig. 22–20C). Generally, fewer air bubbles are trapped on the internal surface if small increments of investment are added and allowed to slowly fill the pattern under vibration than if the investment is smeared over the surfaces of the wax pattern with a brush.

Investment is applied to any external surfaces on

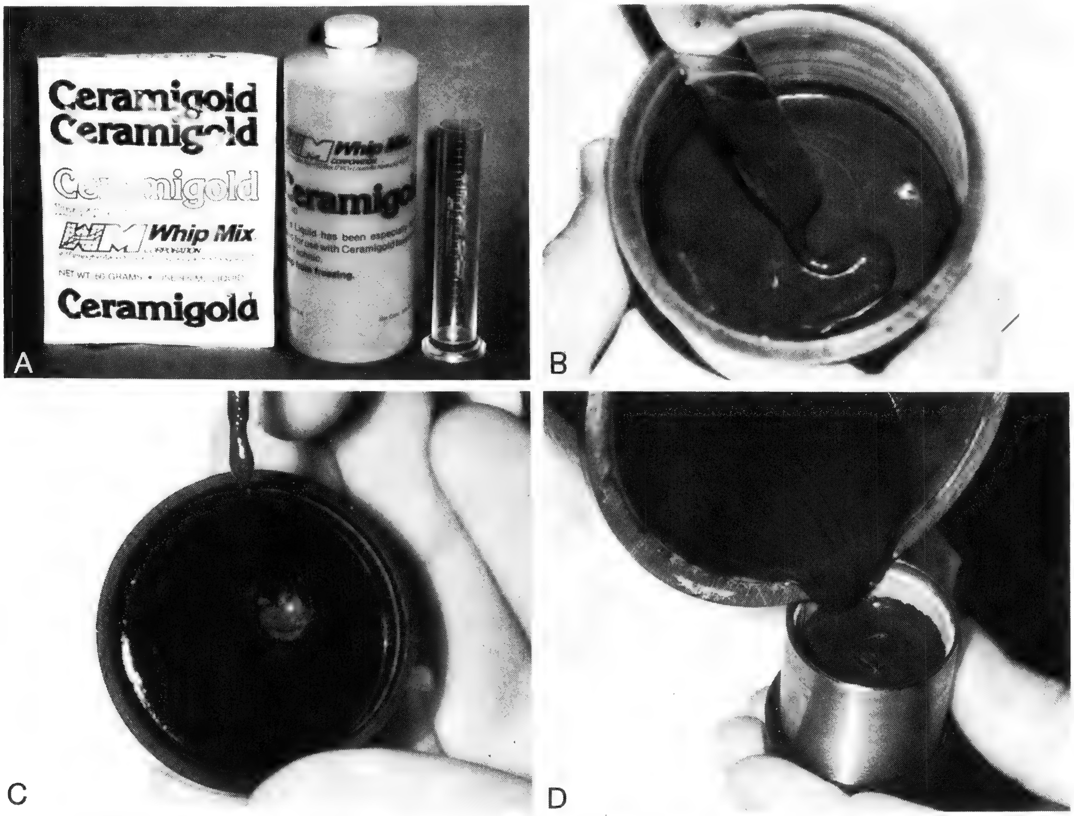


FIGURE 22–20 Vacuum Mixing Hand-Investing Technique Using Phosphate-Bonded Investment

A, Investment package, special liquid, and measuring device.
B, Hand mixing to incorporate all the powder in the liquid.
C, Pattern vibrated until investment fills incisal edge.
D, Investment poured around pattern.

which air would likely be trapped (such as in fossae and grooves on occlusal surfaces). The casting ring is seated over the crucible former, and investment is slowly poured inside the ring until the pattern is covered (Fig. 22–20D). The ring is then set aside until the investment hardens.

The surface smoothness of castings obtained with phosphate-bonded investments appears to be closely related to the amount of time that elapses after mixing and before investing. A pattern invested just prior to setting of the investment is smoother than one that is invested immediately after vacuum spatulation has been completed. This procedure is not recommended for the beginner, who is likely to need all available time when working with a new material. However, with experience the individual can wait after spatulation until the mix just begins to thicken and then expeditiously invest the pattern.

Hygroscopic expansion techniques, as discussed in Chapter 14, are sometimes used in conjunction with base metal alloys to achieve more overall setting expansion so that a more accurate casting can be obtained.

Owing to the higher strength of phosphate-bonded investments, a 45-minute setting time is adequate prior to burnout. If necessary, the ring can also stand for long periods of time without being stored in a humidor or remoistened prior to burnout.

CASTING PROCEDURE

BURNOUT

The crucible former is separated, and the casting ring is placed in a room-temperature burnout furnace. As with any investment that has a high thermal expansion and marked changes in expansion, or even an actual contraction, it is necessary to use slow heating during burnout in order to prevent possible cracking or spalling. Some furnaces have means for slowing the rate of heating. With those that do not, it is advisable to use a two-stage burnout, with the temperature held at 200 to 300° C (392 to 572° F) for at least 30 minutes before completing the burnout.

Although phosphate investments appear to be very strong, they are still subject to a number of disrupting influences during burnout. The wax at first softens and then expands much more than does the investment. During spruing, it is desirable to leave 3 to 6 mm of space around each pattern and to stagger the patterns if several are placed in the same ring. A number of patterns in one plane can exert tremendous pressure and fracture almost any investment. The rapid expansion of the cristobalite at approximately 300° C (572° F) requires slow heating to prevent fracture. Once the temperature reaches 400° C (800° F), the rate of heating can be safely increased.

A maximal burnout temperature of 677 to 704° C (1250 to 1300° F) works well with gold-platinum-palladium alloys. A higher burnout temperature of 760° C (1400° F) is beneficial for casting the gold-palladium alloys. The maximal temperature need only be held until all the carbon residue from the wax is eliminated on the muffle floor, since prolonged burnout times (over 1 hour) are neither necessary nor advantageous. Lengthy burnout times do not cause investment breakdown, but some individuals find that a slightly rougher casting is produced.

Certain high–palladium-content and base metal alloys require higher burnout temperatures of up to 871° C (1600° F) and longer burnout times. The reader should see Table 22–1 for recommendations. This alteration is necessary to ensure a complete casting. Too great a difference between the casting temperature of the alloy and the temperature of the heated investment mold can result in premature freezing of the metal and an incomplete casting. The higher burnout temperature also produces slightly greater thermal expansion. The manufacturer's recommendations and individual experience with the alloy determine the proper temperature and time.

MELTING AND CASTING

Torches using natural gas and air do not produce sufficient heat to melt metal-ceramic alloys. Natural gas and oxygen or propane and oxygen torches are required. The tip used on the torch can have a single orifice for alloys that melt at lower temperatures (such as gold-platinum-palladium). Multiorifice tips are required for the higher-temperature fusing alloys to disperse the heat more evenly and also to encompass the larger ingots of metal encountered with the alloys that have lower specific gravity (Fig. 22–21). Welding goggles should be worn during melting of metal-ceramic alloys to prevent eye damage that can occur from viewing the extremely bright molten alloy (Fig. 22–22).

Induction casting may be used for the higher-temperature fusing alloys. This method is not extensively discussed here, since few schools or dental offices routinely use this equipment. In induction casting, the metal is melted in a furnace rather than by use of a torch. This method can be advantageous for metal-ceramic alloys that are somewhat more sensitive t

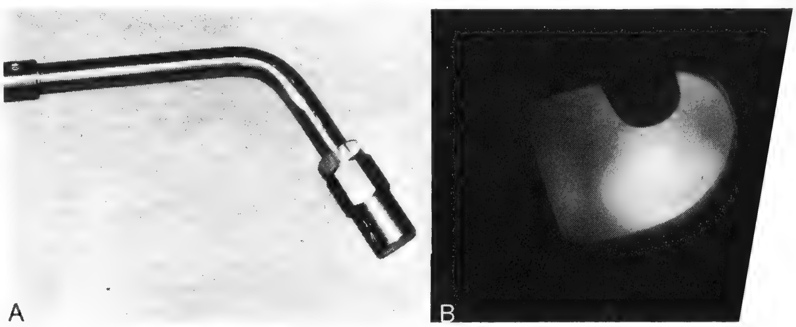


FIGURE 22–21 Use of Multiorifice Torch

A, Multiorifice torch.
B, Flame adjusted so inner blue cones are ¼ inch long.

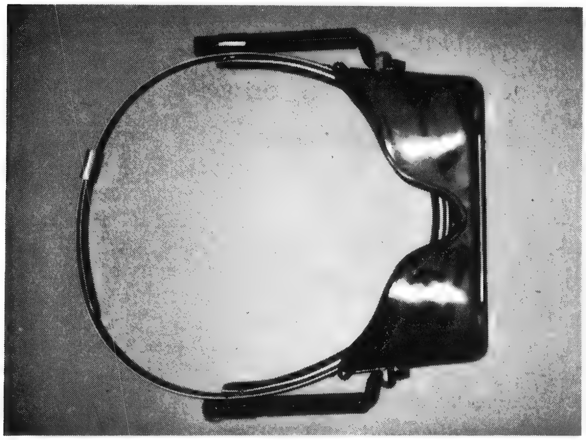


FIGURE 22–22 Welding goggles.

contamination or improper use of a torch. Such equipment tends to reduce the effects of human variables. However, there is no practical difference between these methods in terms of the properties or accuracy of the castings.

Separate casting crucibles should be used for each type of metal-ceramic alloy to avoid cross-contamination. For the same reason, metal-ceramic alloys should not be melted in crucibles previously used to melt conventional crown and bridge alloys.

Casting crucibles are available that are made of clay, quartz, or zirconium. None of these materials causes contamination of the alloys, but the quartz and zirconium crucibles last longer under the more intense heat that is developed when metal-ceramic alloys are melted.

Casting crucibles should not be coated with a layer of flux prior to use, since flux can remove important base metal constituents from the alloy.

Centrifugal casting machines such as the Kerr Centrifico require three windings of the spring for gold-platinum-palladium and gold-palladium alloys. The machine should be wound at least four times for casting alloys with lower specific gravity. The permeability of the phosphate investment is low in relation to that of a gypsum-bonded investment. Therefore, the required casting pressure should be greater than for a gypsum mold.

The amount of excess metal, above that required to fill the mold, should be slightly greater for the alloys with low specific gravity. The principles used to adjust the torch flame and melt the alloy are the same as that discussed in Chapter 15.

After casting, the ring is allowed to bench cool for 5 minutes or until the button ceases to glow red. The ring is then quenched in cold water.

Investment Removal and Cleaning

Phosphate-bonded investments do not readily disintegrate on quenching, and casting retrieval is difficult. A suggested removal technique is to use a plaster knife to cut the investment from each end of the ring until the liner is exposed to allow the investment to be pushed out (Fig. 22–23A). The knife can then be used as a wedge to split the investment and to remove most of the material (Fig. 22–23B). The internal aspect of the casting is debrided by using a smaller more pointed instrument. The bulk of the investment must be removed mechanically by hand, whereas residual material adhering to the casting surface can be eliminated in several ways.

The casting can be cleaned in a container of detergent solution in an ultrasonic cleaner for 15 to 20 minutes, or an air abrasive unit can be used (employing 50-μm aluminous oxide particles). Both of these methods are effective on all types of alloys.

Another method of investment removal can produce an extremely clean surface. The casting is placed in a sealed container of 52 per cent hydrofluoric acid, and the container is subjected to ultrasonic action for 10 to 15 minutes. This technique is limited to certain alloys composed primarily of noble elements, since some metals can be attacked by the acid (such as base metal). The alloy manufacturer's recommendations regarding this procedure should be consulted.

A disadvantage of the hydrofluoric technique is the caustic nature of the acid. Extreme care must be exercised to ensure that none of this acid gets on the skin, since exposure is not immediately discernible and a delayed burn occurs that is very severe. In fact, the acid should not be used unless the user is familiar with first aid techniques and the necessary neutralizing solutions are at hand. Safety goggles should be worn at all times during handling of this material. Another precautionary procedure is to rinse the hands with copious amounts of water after each contact with the acid container.

If known contact occurs, the area must be washed with water and milk of magnesia should be applied. A physician should be contacted if complete elimination of the acid is questionable (such as under a fingernail) or when the exposure was not immediately detected and neutralized. Calcium gluconate injection into the exposed area can be used to reduce permanent damage in severe burn cases.

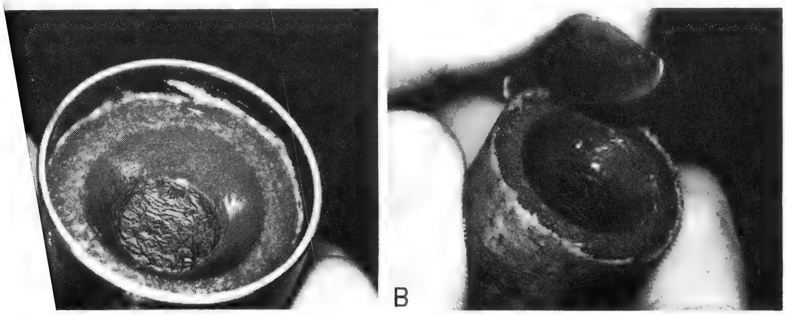


FIGURE 22–23 Devesting Casting

A, Plaster knife used to expose ring liner.
B, Splitting investment mold with a knife.

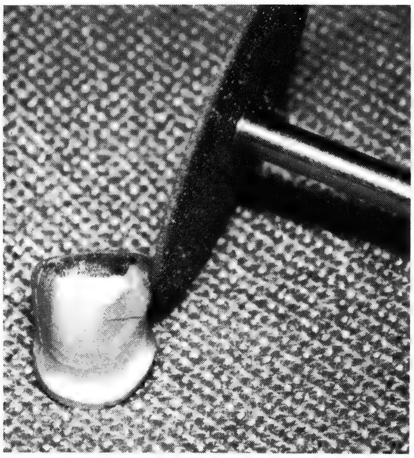


FIGURE 22–24 Sprue removed and normal contour established with separating disc.

A plastic container with a well sealed lid is mandatory to avoid leakage and to contain the fumes that emanate from hydrofluoric acid as it becomes heated during ultrasonic action. Plastic tongs should be used to carefully place the casting in the acid and to remove it without splashing or dripping. When the container is opened, the lid should not be placed on the counter because acid may be inadvertently left behind and unknowingly contacted by another individual.

After the casting has been removed from either the hydrofluoric acid or the detergent solution, it should be thoroughly rinsed to wash away all residual cleaning material.

Preparing the Casting for Porcelain Application

The sprue is removed in the usual manner, and the integrity of the casting is evaluated (Fig. 22–24). Castings with voids in the veneering surface, regardless of their small size, should be discarded, and a new casting should be fabricated. Voids are areas of stress concentration in the final restoration, from which cracks in the porcelain often propagate. Also, the area around a void is often excessively thin, and the casting may not possess adequate resistance to occlusal forces.

The internal surface is inspected, and any small nodules are removed with a number ½ round bur until the casting seats completely and passively on the die. Once the fit of the casting is verified, the surface to be veneered is prepared for the application of porcelain.

The metal thickness of the veneering surface is measured with a gauge* and reduced wherever necessary until a thickness of 0.2 to 0.3 mm is achieved (Fig. 22–25). This gives the casting sufficient strength to resist occlusal forces while providing for an adequate thickness of porcelain. Thicknesses less than 0.2 mm can be present in small isolated areas, but an overall thickness of less than 0.2 mm does not give the framework adequate strength, regardless of the type of alloy used. Castings significantly thicker than this dimension interfere with the esthetic quality of the restoration, since the space available for porcelain is reduced.

The casting thickness is reduced by grinding the surface with rotary instruments. Ideally, the reduction should be performed with the instruments moving across the surface in only one direction as opposed to back and forth. Grinding in different directions drags projections of metal over each other (Fig. 22–26) and often traps within the metal surface contaminants (such as particles of the abrasive instrument) that cannot effectively be removed during subsequent surface cleansing procedures. These particles can interfere with the metal-to-porcelain bond by creating gases during firing and thus forming bubbles in the porcelain. Voids at the metal-opaque junction serve as areas of stress concentration from which cracks in the porcelain can develop.

The instruments most often used for reducing metal thickness include abrasive stones and carbide burs (Fig. 22–27). Carbide burs are extremely efficient when new and cleanly remove metal without dragging it from one area to another. Abrasive stones are probably the most widely used instrument because of their low cost, longevity, and range of available sizes and grits. However, they can produce considerable metal dragging and abrasive particle entrapment when they are used in a back-and-forth grinding motion.

Ideally, the stones should be made of a noncontaminating material such as aluminous oxide, and the abrasive particles should be fused together rather than glued together, since the adhesive is a possible source of contamination. Fewer bubbles are found at the metal-to-ceramic interface when the grinding has been accomplished with a fused stone. Stones in which the abrasive particles are glued together (such as in a separating disc) disintegrate rapidly, whereas a fused stone lasts much longer. A nonfused instrument can safely be used

*Iwanson Metal Thickness Gauge, Pfingst Company, Inc., South Plainfield, NJ 07080.

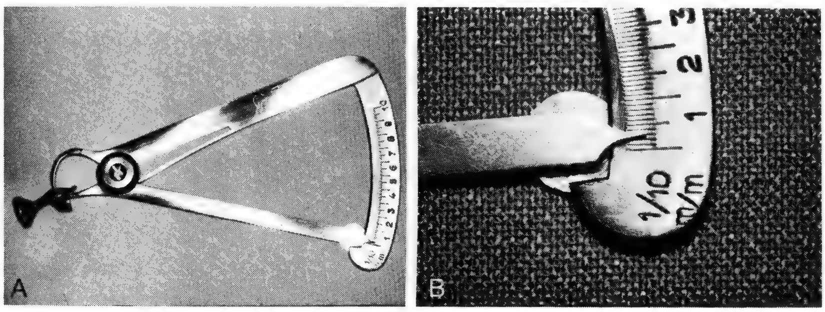


FIGURE 22–25
A,B, Measuring metal thickness with gauge.

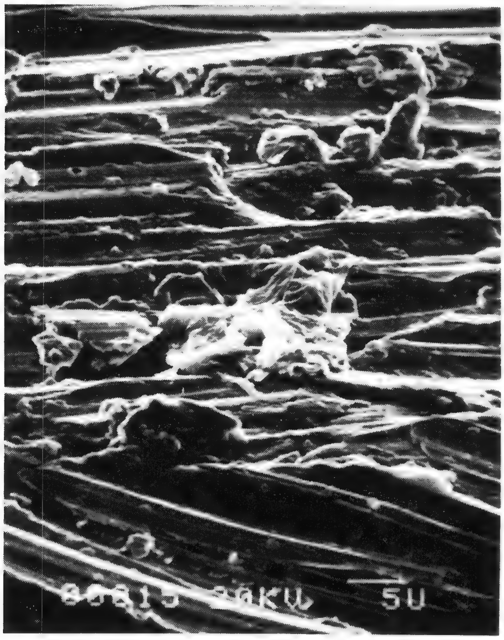


FIGURE 22–26 Scanning electron micrograph of ground surface showing metal projections. Magnification ×1800.

for the initial metal reduction, but to avoid contamination a fused stone should be used for the final reduction.

Instruments used for grinding conventional alloys should not be used on metal-ceramic alloys. This avoids contamination of the metal-ceramic alloy surface with foreign metallic elements. In addition, instruments used on one type of metal-ceramic alloy should not be used on a different metal-ceramic alloy, owing to compositional differences.

The veneering surface should have a rounded form (Fig. 22–28) after it has been reduced. There should be no sharp angles present where different surfaces meet (such as at the labioincisal line angle). Also, the entire surface should be uniformly smooth, not rough and bumpy. The potential for air entrapment below the opaque porcelain is much greater on a rough surface than on a uniformly smooth surface, since it is more difficult to obtain intimate contact between porcelain particles and a rough metal surface.

A definite sharp termination to the veneering area should be established so it is easy to determine where the porcelain application is to be stopped. Areas that are not to be veneered should be smoothed to a satin finish that facilitates removal of porcelain that flows beyond the veneering area, but they should not be polished completely. Establishing the final polish on nonveneered areas is useless, since the metal oxidizes during the firing cycles and must be repolished following porcelain completion.

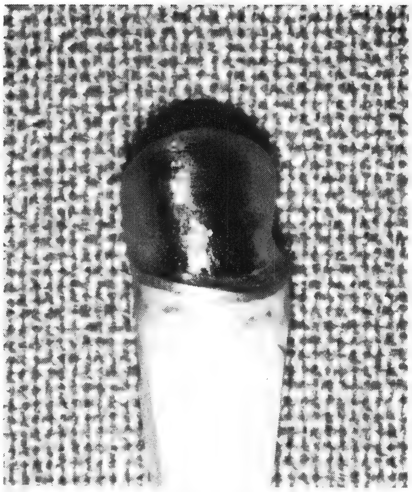


FIGURE 22–28 Final form of prepared casting.

After the grinding procedures are complete, the metal casting must be thoroughly cleansed to create a surface that properly reacts with the porcelain. For gold-platinum-palladium and gold-palladium alloys, this is most effectively accomplished by placing the casting in a sealed container with clean 52 per cent hydrofluoric acid and ultrasonically cleaning it for 20 minutes. There are other commercially available solutions, but these require considerably longer time to achieve the same degree of cleanliness.

Alloys can also be cleaned by using an air-abrasive unit with fine-grit aluminous oxide particles (50 μm) followed by 20 minutes of ultrasonic cleaning in distilled water (Fig. 22–29). Alloys that are not compatible with hydrofluoric acid (such as base metal) are cleansed in this manner.

The casting is next placed on a firing tray (Fig. 22–30A) and heated in a porcelain furnace (Fig. 22–30B,C) according to the alloy manufacturer's suggestions. The heating drives combustible contaminants, such as oils and gases, from the metal surface. This heating cycle historically has been called the "degassing" cycle, but its purpose is not only to decontaminate or degas the metal but also to oxidize the surface (Fig. 22–30D).

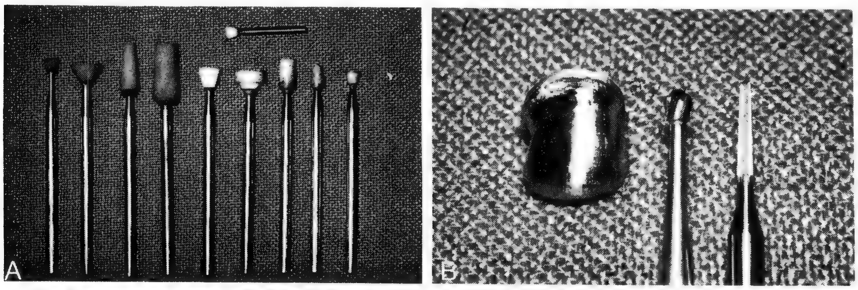


FIGURE 22–27

A, Abrasive stones.
B, Carbide burs.

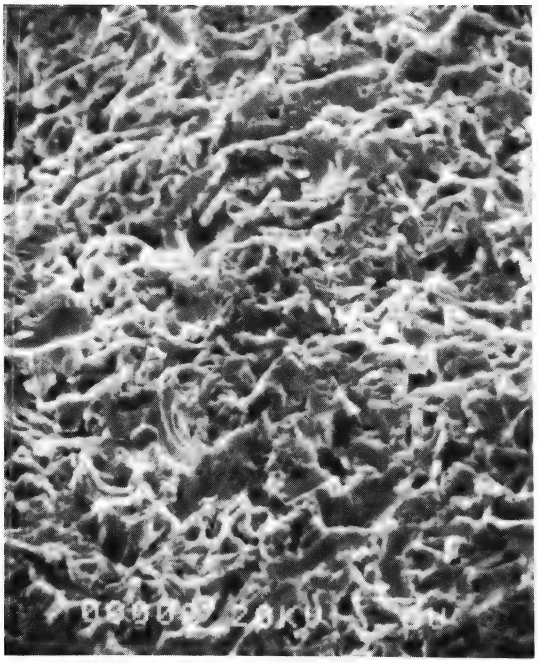


FIGURE 22–29 Electron micrograph of metal-ceramic casting after air abrasion with aluminous oxide. Magnification ×1800.

The temperature used should be about 28° C (50° F) above the highest fusion temperature for the particular brand of porcelain being used. The heating is generally done in a vacuum but not with all metals (the alloy manufacturer should be consulted). However, some general recommendations can be given.

For gold-platinum-palladium alloys, the casting is held for 10 minutes in a vacuum at the established temperature, then removed and allowed to cool in air. The casting is ready for the application of opaque porcelain when it has cooled. Gold-palladium alloys that contain silver are handled in a similar manner.

Many of the nonsilver gold-palladium alloys, many of the high–palladium-content alloys, and all base metal alloys are handled differently because there is a tendency for the development of excessive amounts of surface oxide, which interfere with the metal-ceramic bond. The casting is decontaminated by heating as recommended to produce an oxide layer. The casting is air-abraded to remove the oxide layer and ultrasonically cleaned in distilled water for 20 minutes, and the opaque porcelain is applied. Sufficient oxide forms during the porcelain firing cycles to achieve a good bond. If the initial oxide layer is allowed to remain on these particular alloys, subsequent porcelain firings produce excessive amounts of oxide, and the porcelain may separate from the castings either in the laboratory or during function. The separation occurs through the excessively

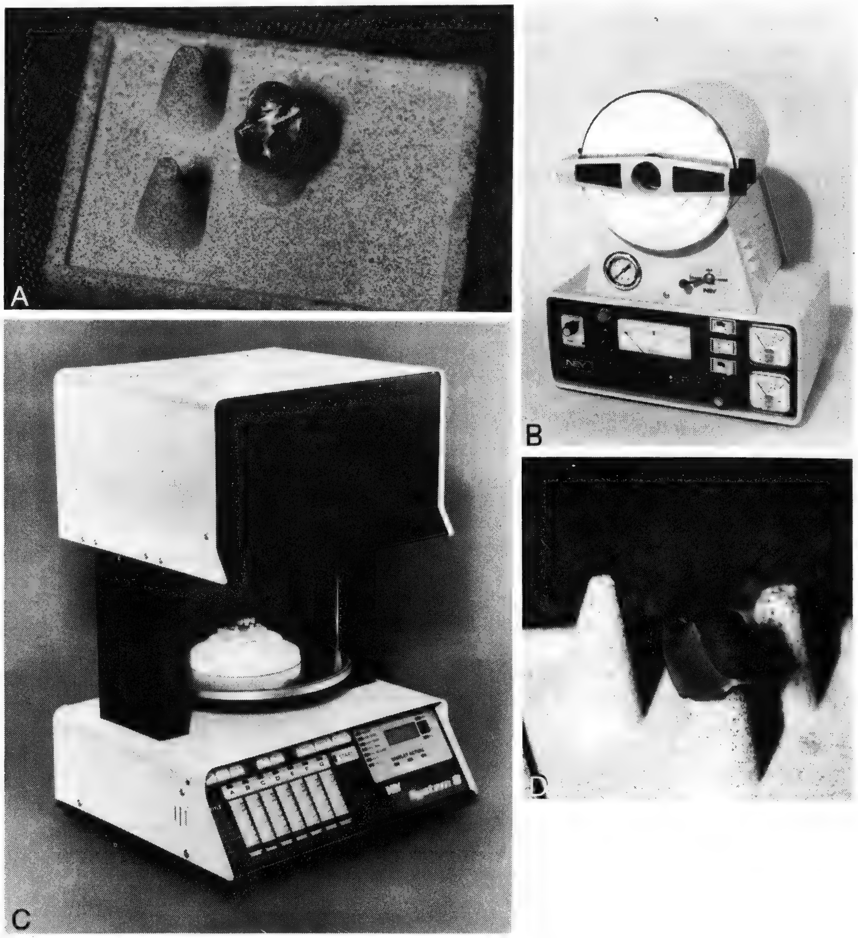


FIGURE 22–30
Oxidizing the Casting

A, Casting on firing tray.
B, Ney Mark III modular furnace. (Courtesy of The J. M. Ney Company.)
C, Ney System 8 programmable furnace. (Courtesy of The J. M. Ney Company.)
D, Oxidized casting after firing in furnace.

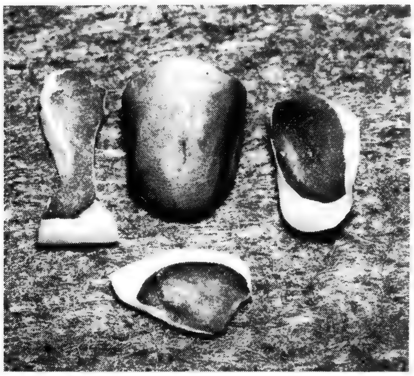


FIGURE 22–31 Base metal alloy with bond failure caused by excessive oxidation.

thick oxide layer, which appears to be the weakest link in the bonding system (Fig. 22–31). The alloy manufacturer's instructions for preparation of the metal surface must be followed, since variations occur between different alloy brands even though they possess similar compositions.

When the oxidation is properly controlled, restorations possessing an adequate metal-to-ceramic bond can be achieved with all of the alloy systems.

The veneering surface must not be touched following the decontamination procedures. The casting should be handled only with a clean instrument such as a hemostat or the casting can be covered with clean gauze or a similar material and then picked up by the fingers.

PORCELAIN APPLICATION AND COMPLETION

Opaque Application

With the casting held by hemostats, the veneering surface is very slightly moistened with the liquid recommended for mixing the opaque porcelain. Vibration of the casting, as is produced by drawing a serrated metal instrument across the handles of the hemostat, facilitates the penetration of the microcrevices of the veneering surfaces by the liquid. Subsequently, the opaque porcelain follows the liquid into the irregularities of the metal surface without significant air entrapment.

The opaque porcelain is mixed to a thick consistency as described in Chapter 19 (Fig. 22–32A). A bead is picked up by using the tip of a brush and placed on the casting (Fig. 22–32B). Additional increments are then applied to cover the veneering area. The hemostats are gently tapped with a metal instrument to facilitate the flow of a uniform layer of material over the casting surface (Fig. 22–32C). The casting is quickly held in front of the open muffle of the furnace until the liquid evaporates and fixes the position of the opaque porcelain. The opaque porcelain is then dried completely by placing it on a firing tray in front of the open furnace muffle for 2 to 5 minutes (Fig. 22–32D). It is fired in a vacuum according to the manufacturer's instructions (Fig. 22–32E).

The opaque porcelain should mask the underlying metal casting without an excess thickness, which could create an esthetic liability by unduly influencing the final shade. While the opaque porcelain can be applied in one layer by an experienced individual, it is difficult to determine when excess material is present. For this reason, many individuals apply and fire a very thin layer of opaque followed by a second coating to achieve the minimal thickness necessary to mask the metal.

A fired opaque thickness of 0.1 mm adequately masks the underlying metal for most porcelain shades. When the fired opaque is moistened, a very slight hint of grayness from the metal should be apparent with the darker shades of porcelain. The lighter shades of porcelain require a greater thickness of fired opaque porcelain (0.15 mm), since grayness appearing through the moistened opaque adversely affects the final color match.

When a large number of castings are being veneered as a group, it is possible to spray opaque on the veneering surfaces with an air brush* and compressor (Fig. 22–33A).† The opaque porcelain must be mixed to a much thinner than usual consistency to allow spraying. Once mastered, this process allows the rapid application of very uniform layers of opaque porcelain (Fig. 22–33B). The disadvantages are that (1) large amounts of material are wasted as overspray; (2) it is somewhat messy; and (3) areas of the casting not to be veneered (such as the internal surface) are covered and must be cleaned prior to firing (Fig. 22–33C).

Dentin and Enamel Application

The fused opaque layer is moistened with the appropriate liquid, and then the mixed dentin porcelain is incrementally applied until a slightly oversized form of the tooth is established (Fig. 22–34). Since porcelain shrinks at firing, the dentin buildup should be 10 to 20 per cent larger in all dimensions than the final desired size.

Maintaining the proper moisture level is one of the keys to easy manipulation and subsequent dense packing of the powder particles. While the porcelain is being applied, an absorbent material is held in close proximity so it can be brought into contact with the powder if the porcelain should start to slump (Fig. 22–34D). When the excess moisture has been removed, the absorbent material is removed from contact with the porcelain to prevent excessive drying. If the porcelain becomes too dry, additional moisture must be added to allow subsequent additions to properly unite with previously applied material. The best means of uniformly remoistening porcelain is to spray the surface with a mist of distilled water from a refillable atomizer such as those designed for dispensing perfume (Fig. 22–35). Addition of moisture may also be accomplished by touching a wet brush to the porcelain surface.

The oversized dentin buildup is partially condensed, allowing the porcelain to attain sufficient body so that a portion can be safely carved away and replaced with enamel porcelain where translucency is desired (Fig.

*Paasche Airbrush, Paasche Company, Chicago, IL 60614.

†Model 180-I Oilless Compressor, Badger Airbrush Company, Franklin Park, IL 60131.

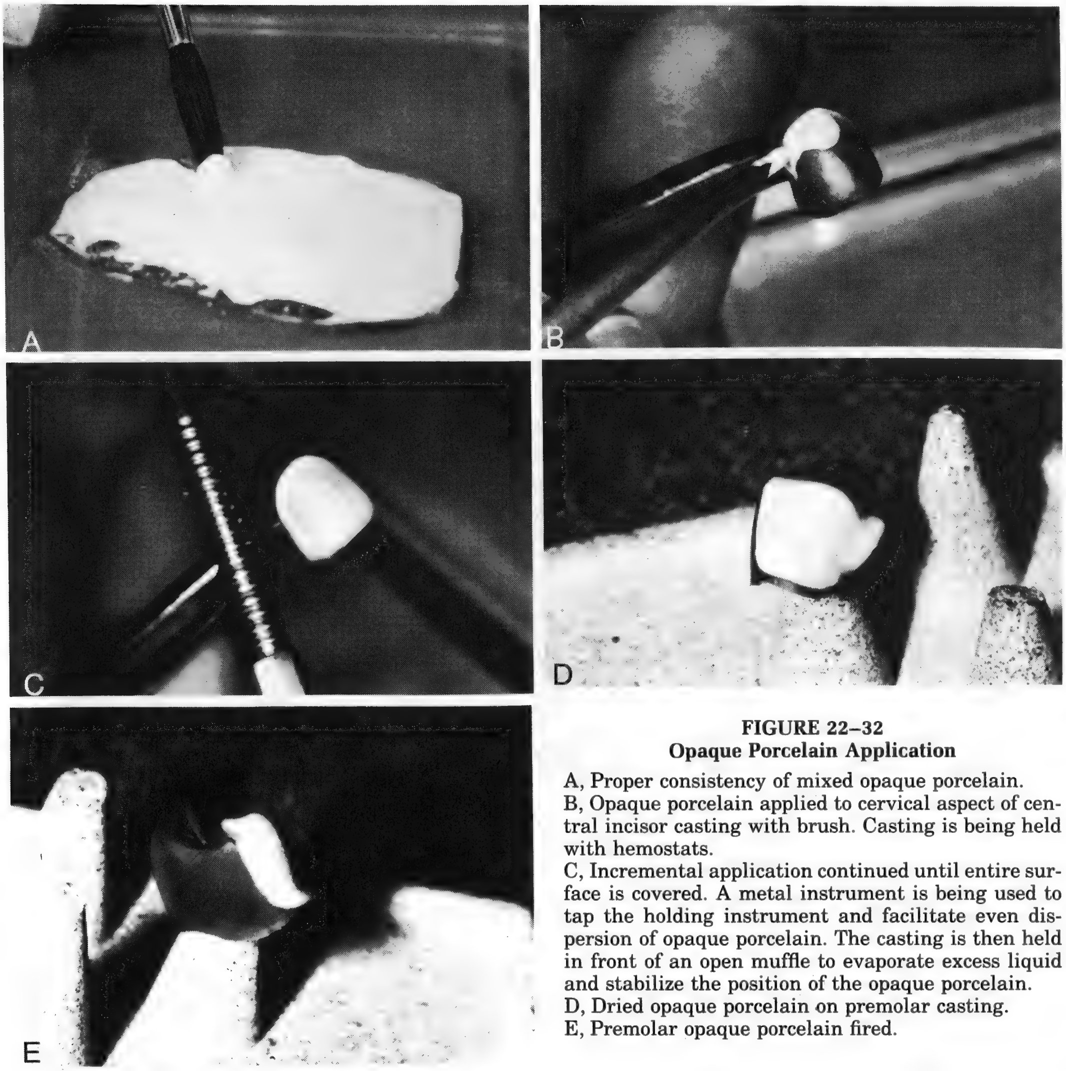


FIGURE 22–32
Opaque Porcelain Application

A, Proper consistency of mixed opaque porcelain.
B, Opaque porcelain applied to cervical aspect of central incisor casting with brush. Casting is being held with hemostats.
C, Incremental application continued until entire surface is covered. A metal instrument is being used to tap the holding instrument and facilitate even dispersion of opaque porcelain. The casting is then held in front of an open muffle to evaporate excess liquid and stabilize the position of the opaque porcelain.
D, Dried opaque porcelain on premolar casting.
E, Premolar opaque porcelain fired.

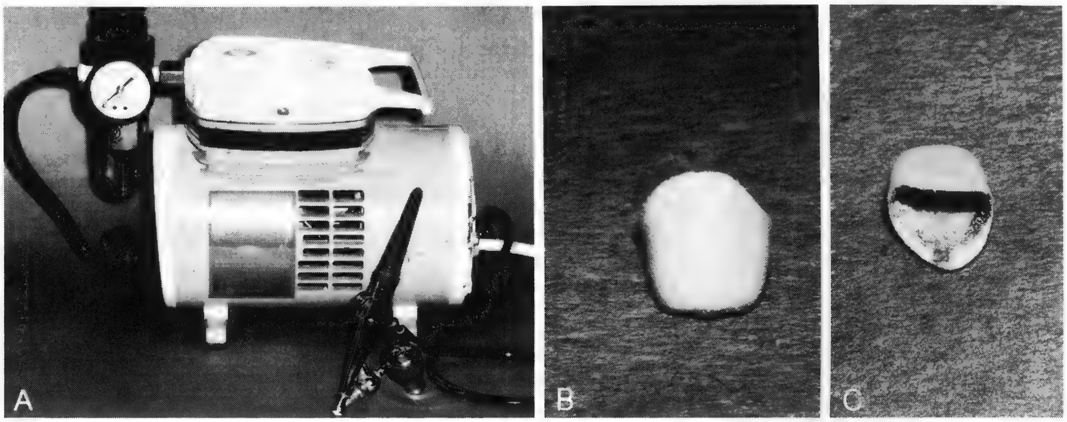


FIGURE 22–33 Spraying Opaque Porcelain

A, Spraying equipment.
B, Sprayed facial surface.
C, Internal surface. Note the overspray, which must be removed before firing.

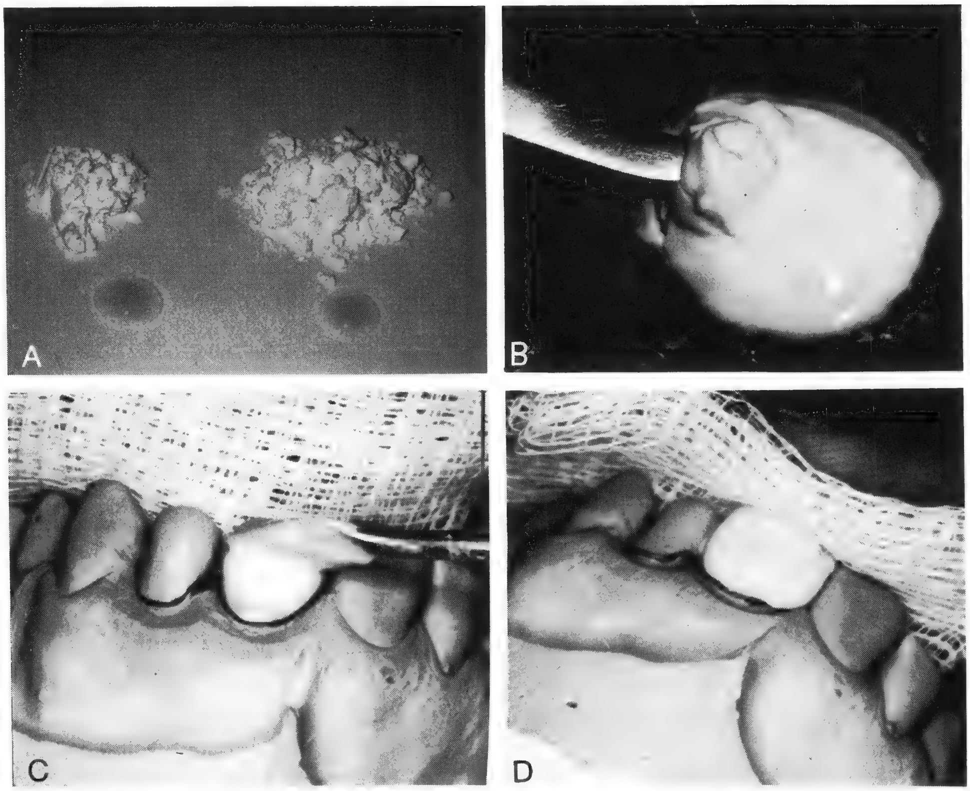


FIGURE 22–34 Dentin Porcelain Application
A, Dentin and enamel powder placed on glass slab with appropriate liquids.
B, Dentin mixed to proper consistency. Note that when a metal instrument is drawn through the porcelain the material resists slumping.
C,D, Slightly oversized crown contour established incrementally with dental porcelain.

22–36A). A more natural-appearing blend of dentin and enamel is achieved by layering the two materials together rather than firing the dentin and then grinding the porcelain to create room for enamel.

The extent of the dentin cutback is based on a clinical evaluation and measurement of the location of translucency in the surrounding natural teeth (see Chapters 24 and 25). Thin-bladed metal instruments* are well suited for carving away the dentin porcelain (Fig. 22–36B), or a number 11 scalpel blade can be used (Fig. 22–36C).

FIGURE 22–35 Perfume atomizer filled with distilled water.

The cutback for enamel placement should produce the greatest faciolingual thickness of enamel interproximally and at the incisal edge. Incisally, the cutback should extend to the faciolingual center of the incisal edge on adjacent teeth. Interproximally, it should extend slightly lingually to the proximal contact with adjacent teeth. The thickness should then gradually taper cervically to the point at which the translucency terminates (Fig. 22–36D).

If additional incisal translucency is required, some dentin porcelain can also be carved away on the lingual aspect of the incisal edge, and enamel porcelain can be placed in this area. It is important to have some dentin porcelain extend to the incisal edge to prevent the formation of a definite line of demarcation in the fired crown at which the dentin ends and the enamel begins.

It is usually necessary to remoisten the dentin porcelain prior to adding enamel, since dehydration often occurs during the carving procedure (Fig. 22–37A).

*Porcelain sculpturing instrument number 001 017, Belle de St. Clair, Van Nuys, CA 91406.

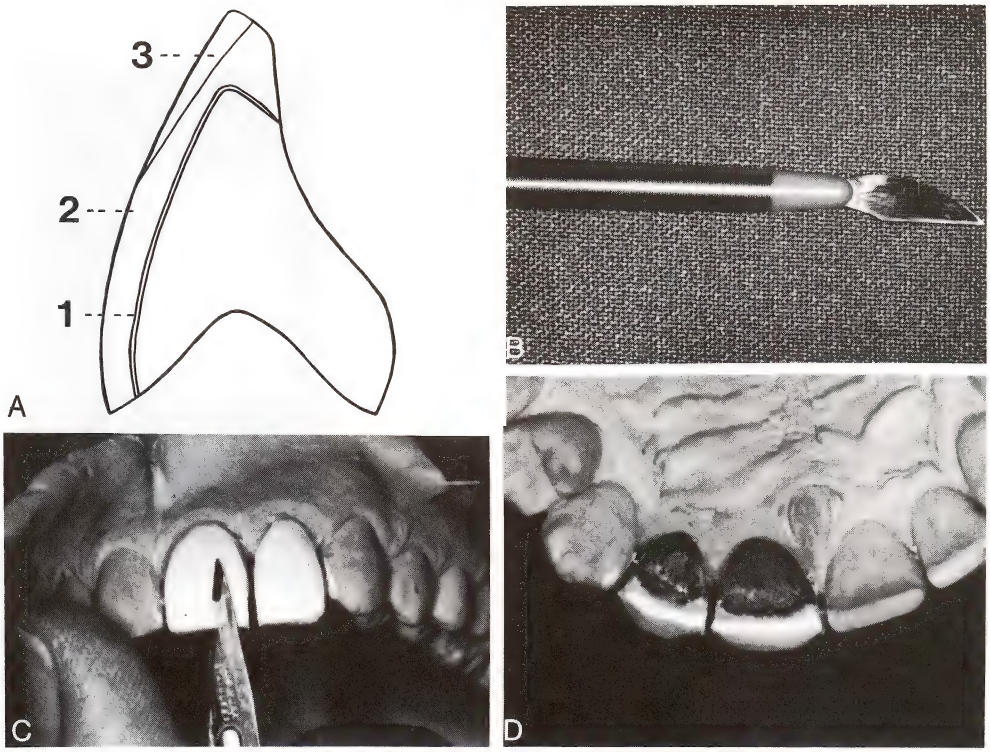


FIGURE 22–36 Cutback for Enamel Porcelain

A, Diagram of porcelain distribution: (1) opaque porcelain, (2) dentin porcelain, (3) enamel porcelain.
B, Thin-bladed porcelain-carving instrument.
C, No. 11 scalpel blade used to remove dentin from incisal aspect of facial surface.
D, Incisal view of cutback.

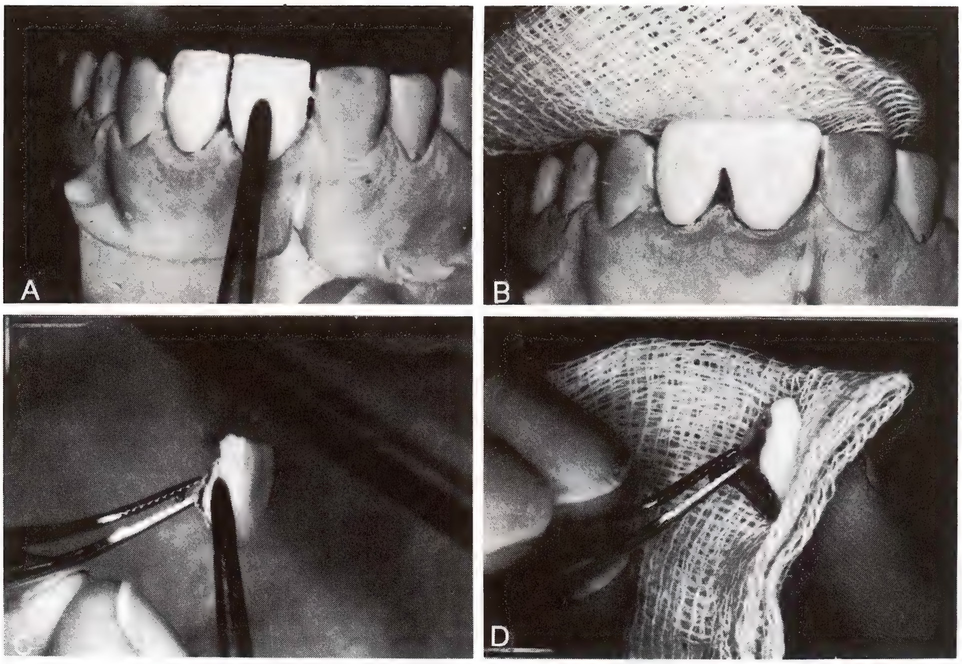


FIGURE 22–37 Enamel Porcelain Application

A, Cutback dentin being remoistened with wet brush.
B, Enamel porcelain applied until oversized form is achieved.
C, Additional enamel porcelain being applied proximally after crown is removed from working cast.
D, Condensing the restoration.

Mixed enamel porcelain is added to the cutback dentin until the oversized crown form is again achieved (Fig. 22–37B).

The casting and completed buildup must now be removed from the working cast and held with hemostats so that enamel porcelain can be added interproximally to allow the restoration to possess adequate mesiodistal dimension after the firing shrinkage occurs (Fig. 22–37C). Remoistening may again be necessary prior to adding porcelain proximally. Prior to removal, it is mandatory that excess porcelain cervical to the proximal contacts (which is locked into undercut areas) be carved away so that removal from the working cast does not fracture previously applied porcelain.

Condensation is accomplished, as described in Chapter 19, by tapping the instrument that holds the casting with another metal instrument while absorbent material is held against the porcelain to remove excess moisture as it rises to the surface (Fig. 22–37D). The process is repeated until the porcelain powders are densely packed.

Prior to firing, a moistened brush is used to remove porcelain that has flowed onto areas not designated for veneering. Special attention must be paid to marginal areas and the internal surface (Fig. 22–38). Porcelain fused on these areas can detrimentally affect casting fit. Thin amounts of fused porcelain are difficult to detect, and removal by grinding can deleteriously affect the metal contour and casting fit.

The completed buildup is placed on a firing tray in front of the open muffle of the furnace to dry for a period of 10 to 15 minutes. Incomplete drying leads to steam formation when the porcelain is placed in the furnace and an explosive disruption of the condensed material (Fig. 22–39). After proper drying, the porcelain is fired in a vacuum according to the manufacturer's instructions (Fig. 22–40A,B).

The fired restoration is returned to the working cast, and the proximal contacts are adjusted so that the restoration seats fully on the working cast. Ideally, there should be a slight excess of porcelain in all areas. However, it is common to find deficient areas in which porcelain must be added to achieve the slightly oversized dimensions that allow shaping to the final form. Additional porcelain is applied, condensed, and dried in front of the open muffle. The drying time can be reduced to 5 minutes, since less porcelain has been applied. The porcelain is again fired in a vacuum according to the manufacturer's instructions (Fig. 22–40C,D).

FIGURE 22–38 Porcelain particles being removed from inside of casting with moistened brush.

FIGURE 22–39 Defective porcelain, which was caused as steam formed when the incompletely dried buildup was fired.

The slightly oversized form of the restoration should be complete after the second firing. If not, the previous procedure is repeated to achieve adequate bulk.

SHAPING

Shaping is accomplished by using diamond instruments or abrasive stones, such as the Busch Silent.*

The restoration is placed on the mounted working cast, and the proximal contacts are refined as needed. Cervical adjustment may also be necessary to eliminate impingement occurring between the porcelain and the gingival tissue on the cast.

When the restoration is fully seated, the occlusion is adjusted, the final shape established, and the surface characterization completed. Chapter 23 provides more information regarding shaping of porcelain. Shape and surface detail as related to esthetics are discussed in Chapter 25.

GLAZING

The completely shaped and characterized restoration must be ultrasonically cleaned in distilled water for 5 minutes to remove any surface debris and contaminants that could produce dark specks or discoloration when the porcelain is glazed.

Glazing is accomplished as previously described by either (1) heating the porcelain to the point at which the surface melts and flows to produce a natural sheen on the porcelain or (2) applying a layer of porcelain glaze powder to the surface and heating the restoration until the layer of applied glaze fuses. A commonly used technique employs a combination of these procedures

*Busch Silent Stones, Pfingst and Company, Inc., South Plainfie NJ 07080.

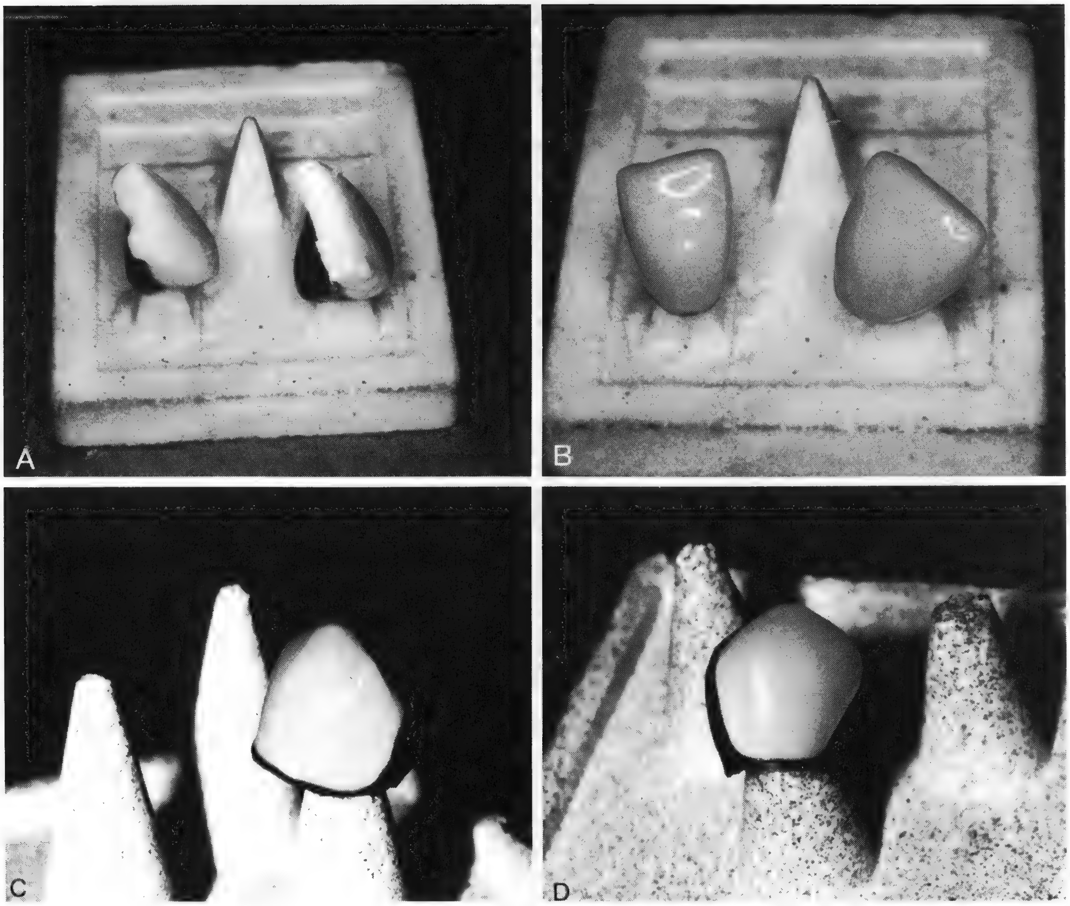


FIGURE 22–40

A, Crowns being dried in front of porcelain furnace.
B, Fired crowns.
C, Appearance of premolar crown after first vacuum firing. Note the deficient cervical contour.
D, Second porcelain application fired to achieve a slight excess of fused material.

Porcelain glaze powder is mixed, a thin layer is applied on the surface, and the restoration is heated until the surface porcelain melts, incorporating the applied glaze into the molten surface. This technique ensures that minor surface voids are filled and that a properly glazed restoration is achieved.

If surface stains are also needed for final color modifications, a thin layer of glazing porcelain should be applied first to fill any surface pits. This prevents stain from accumulating in the defects by filling them first with colorless glaze powder, thus preventing the development of disfiguring colored specks on the surface of the restoration. (The reader should see Chapter 25 for details regarding surface staining.)

The restoration is placed on a firing tray and allowed o dry in front of the open muffle for 5 minutes. Glazes r surface stains turn chalky white when dry. The work then introduced into the furnace, and the temperature raised to the manufacturer's recommended point and l until the desired glaze is achieved (Fig. 22–41). firing is done in air, not in vacuum, so that any rnal bubbles present are not brought to the surface. restoration is removed from the furnace when the proper glaze is achieved and is allowed to cool under a protective glass cover.

Alloy Polishing

The metal becomes darkened because of oxidation during the porcelain firing cycles. This oxide is removed and the final polishing procedures are accomplished in the usual manner with fine paper discs or rubber instruments (Fig. 22–42A). Care must be exercised when the oxide is removed so as not to allow the coarser abrasives used in the initial steps to contact the porcelain and remove the surface glaze (Fig. 22–42B,C). An unglazed surface is rougher and accumulates plaque and stain more readily than does a glazed surface.

The final lustre is developed by using tripoli and rouge, which do not deleteriously affect the porcelain glaze. However, these agents often accumulate in surface pits that may be present but can generally be removed by ultrasonic cleaning of the restoration in a detergent solution or chloroform for 10 to 20 minutes.

The restoration is then ready for clinical evaluation,

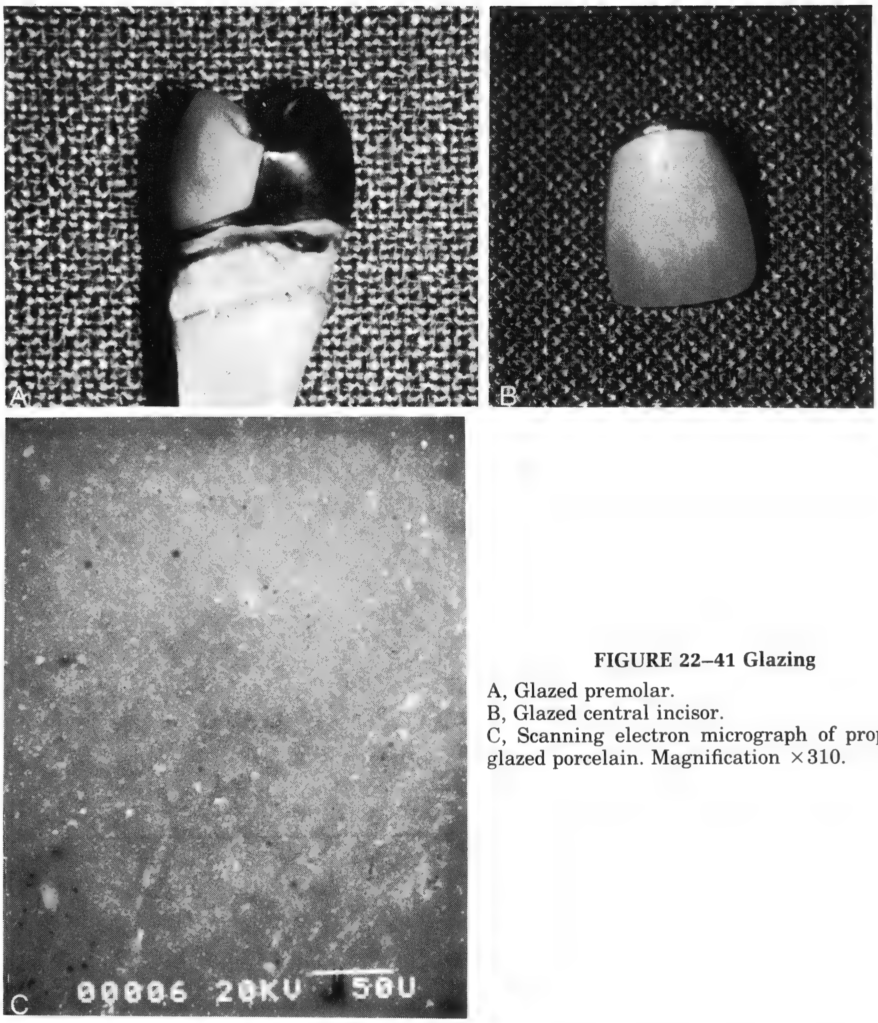


FIGURE 22–41 Glazing

A, Glazed premolar.
B, Glazed central incisor.
C, Scanning electron micrograph of properly glazed porcelain. Magnification ×310.

adjustment, and cementation. These procedures are discussed in Chapter 17.

COLLARLESS METAL-CERAMIC CROWNS

The cervical collar of metal present on metal-ceramic restorations optimizes good marginal fit and cervical contour. However, the presence of metal is esthetically unacceptable in certain clinical situations. For this reason, many laboratory technicians reduce the facial metal collar to a fine line in an attempt to improve the esthetic result. This technique, however, has many disadvantages.

The thin portion of metal is less noticeable but still produces some unnatural cervical coloration, since the opaque porcelain approximates the external surface as the margin is approached. Also, the thin metal has a tendency for distortion during heating, a condition that can lead to an unacceptable fit in the final restoration. Another significant problem is that many restorations of this design are overcontoured cervically, which increases the potential for plaque accumulation at the dentogingival junction and, in time, gingival inflammation.

The collarless metal-ceramic restoration is a better esthetic alternative to the conventional metal-ceramic crown (Fig. 22–43). No metal or opaque porcelain is located at the facial finish line, and the facial dentin porcelain thickness is therefore more uniform. Also, the restoration can be fabricated to have accurately fitting margins and normal cervical contour.

Indications and Contraindications

Collarless metal-ceramic restorations are indicated in situations requiring improved cervical esthetics and the structural advantages of a metal-ceramic restoration. They are particularly advantageous when gingival recession is likely, as in a young patient (Fig. 22–44), a patient with thin finely textured gingiva, or a patient with prominent maxillary canines. The finish line can be placed at the gingival crest or located supragingivally where there is less risk of tissue trauma. Also, if the restoration must be extended subgingivally, treatment

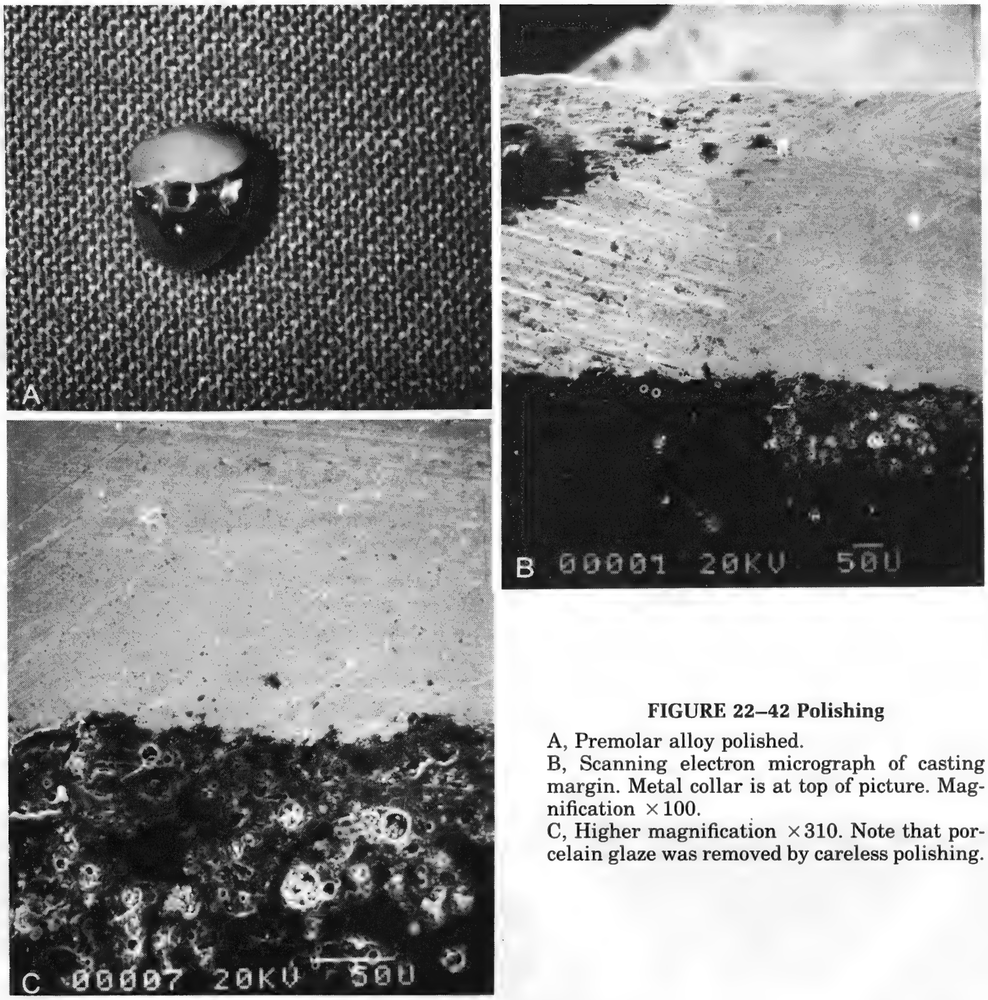


FIGURE 22–42 Polishing

A, Premolar alloy polished.
B, Scanning electron micrograph of casting margin. Metal collar is at top of picture. Magnification ×100.
C, Higher magnification ×310. Note that porcelain glaze was removed by careless polishing.

can be performed without fear that a metal collar later will be exposed (Fig. 22–45). Patients with a high smile line or thin teeth (Fig. 22–46) find this type of restoration esthetically superior because there is no cervical band of metal and uniform dentin porcelain thickness is present in the cervical third. Teeth that have exposed root surfaces or an alignment that does not permit the preparation to be extended beneath the gingival tissue can be esthetically restored in this manner (Fig. 22–47).

The elimination of the cervical band of metal results in a less rigid casting, and this may contraindicate its use as a retainer for fixed partial dentures in areas of high stress. Also, an irregular facial finish line makes it difficult, if not impossible, to fabricate collarless restorations with accurately fitting margins. A facial shoulder finish line is mandatory for the proper fabrication of these restorations. This restoration is not indicated in situations in which this type of finish line cannot be established.

Fabrication Techniques

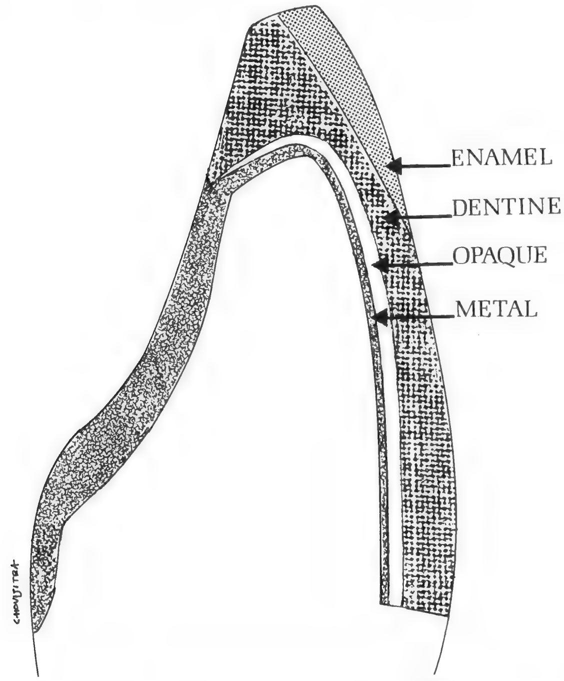
Four techniques have been developed for fabricating collarless metal-ceramic crowns. Advantages and disadvantages are inherent in each technique, but all are difficult and require considerable skill and meticulous attention to detail.

Attaching Platinum Foil Matrix After Casting

One method of fabricating a collarless metal-ceramic restoration involves attaching platinum foil to the casting after it has been contoured for porcelain application. The authors prefer this method because it consistently produces sharp margins. There are several methods of attachment currently in use, which are discussed here along with the technical procedures.

Production of Primary Die and Working Cast

An impression is made of the prepared tooth, preferably with a material with long-term dimensional stability such as poly (vinyl siloxane). It is poured as usual in die stone to produce a primary die and working cast. The die is trimmed, and the working cast is articulated (Fig. 22–48).



COLLARLESS METAL-CERAMIC CROWN

FIGURE 22–43

FIGURE 22–46 Both mandibular incisors and left lateral incisor restored with collarless metal-ceramic crowns.

Production of Secondary Die and Working Cast

Since a platinum foil matrix cannot be removed from a cervical undercut (Fig. 22–49A), a die lacking such undercuts is advantageous. The first step in this process is to block out the facial cervical undercut on the die with a hard wax. The blockout should extend 3 mm cervically to the facial finish line and 1 mm lingually to the shoulder termination interproximally (Fig. 22–49B,C). An elastomeric tube impression is then made

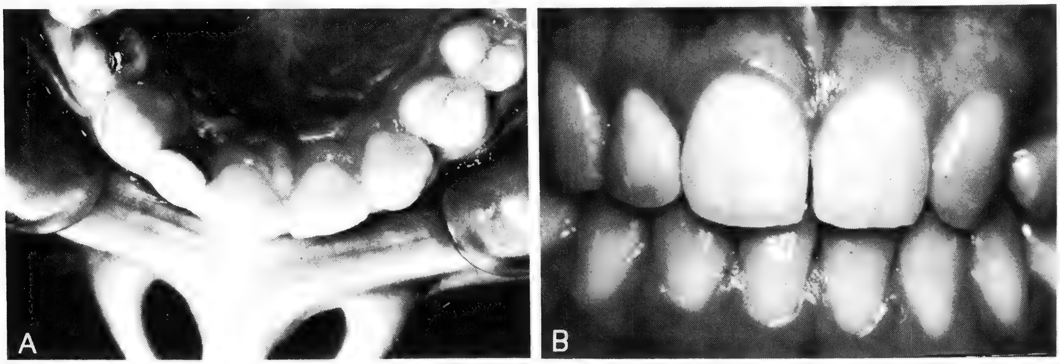


FIGURE 22–44

A, Mirror view of malformed lateral incisor restored with collarless metal-ceramic crown.
B, Facial view.

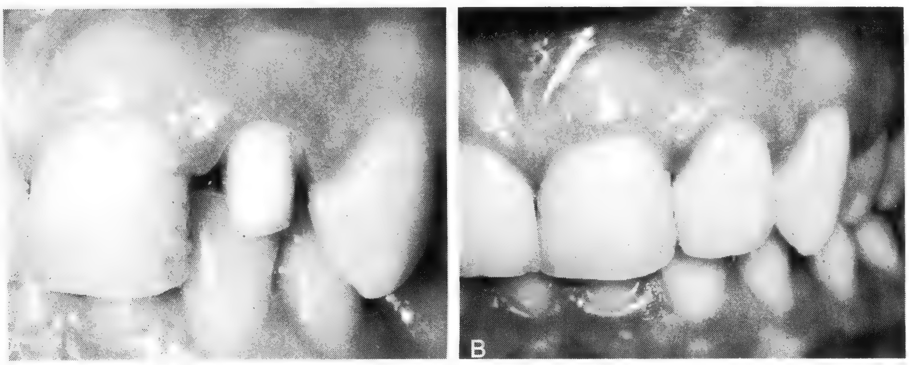


FIGURE 22–45

A, Lateral incisor has been prepared with a subgingival finish line.
B, Facial view of restoration.

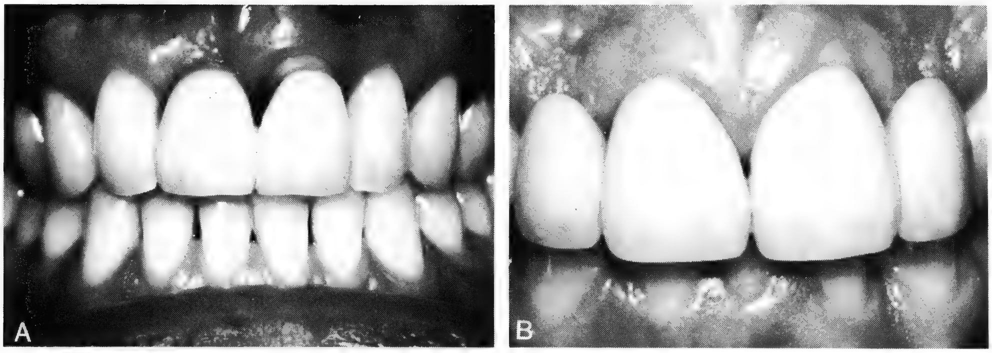


FIGURE 22–47
A,B, Supragingival margins.

of the blocked out die and poured in die stone that has been vacuum-mixed at the lowest water-powder ratio recommended by the manufacturer. The stone is stacked up so that the hardened excess can be trimmed into the shape of a root (Fig. 22–49D). The root portion is trimmed so it tapers toward the apex. A working cast is made by placing the blocked out die into the original full arch elastomeric impression. The die is fixed in position with sticky wax, the root is lubricated with a thin film of petroleum jelly, and dental stone is poured into the impression. A removable die working cast is thus obtained that facilitates the laboratory fabrication (Fig. 22–49E,F). Some individuals prefer to place block-out material on the original die and not to fabricate a separate blocked out stone die and associated working cast.

Casting Fabrication

Using the die and mounted working cast, the pattern is waxed to full contour, and the area to be veneered is carved away. The finished pattern is made without the usual cervical collar (Fig. 22–50A). It is invested and cast as previously described.

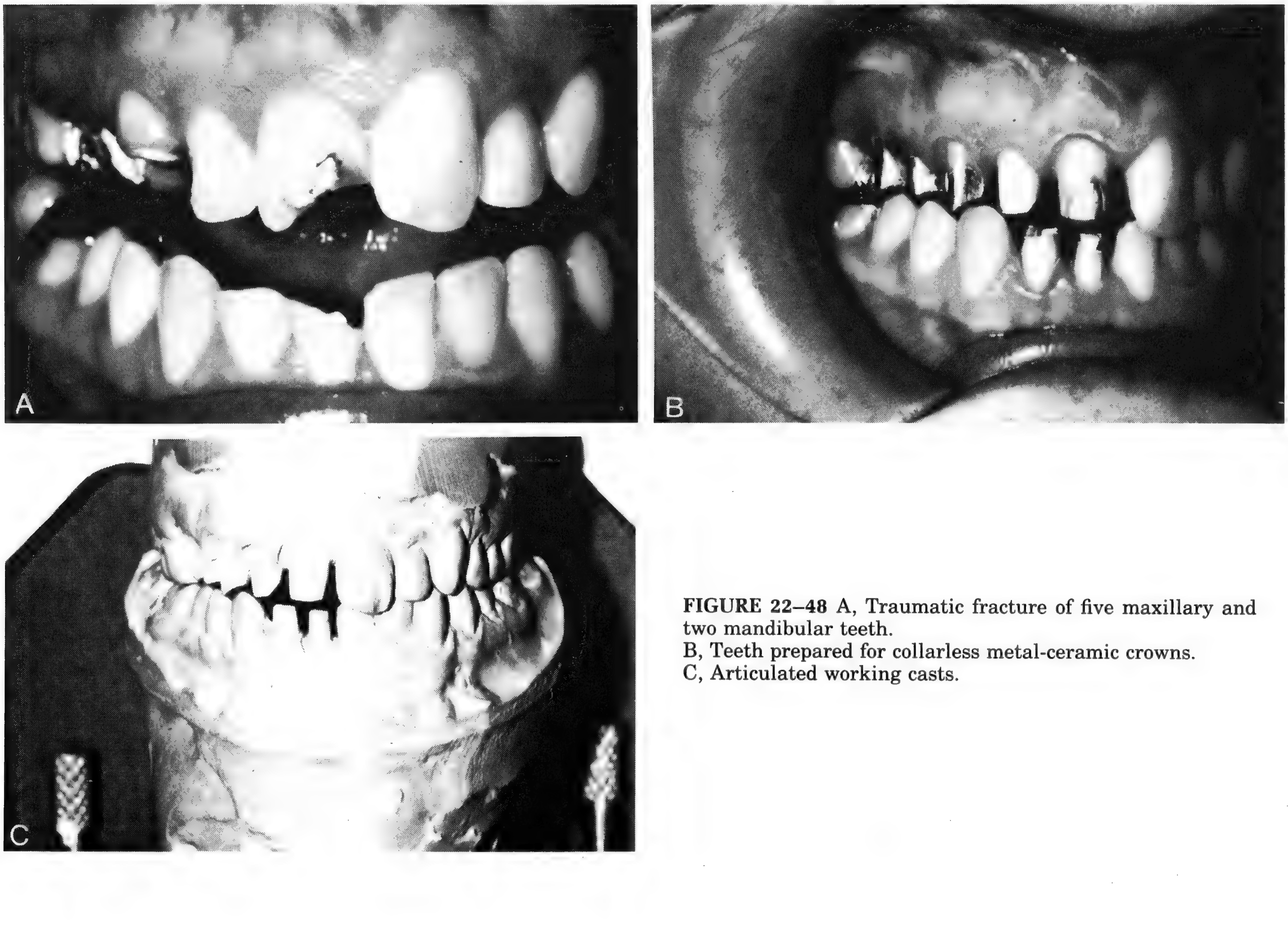


FIGURE 22–48 A, Traumatic fracture of five maxillary and two mandibular teeth.
B, Teeth prepared for collarless metal-ceramic crowns.
C, Articulated working casts.

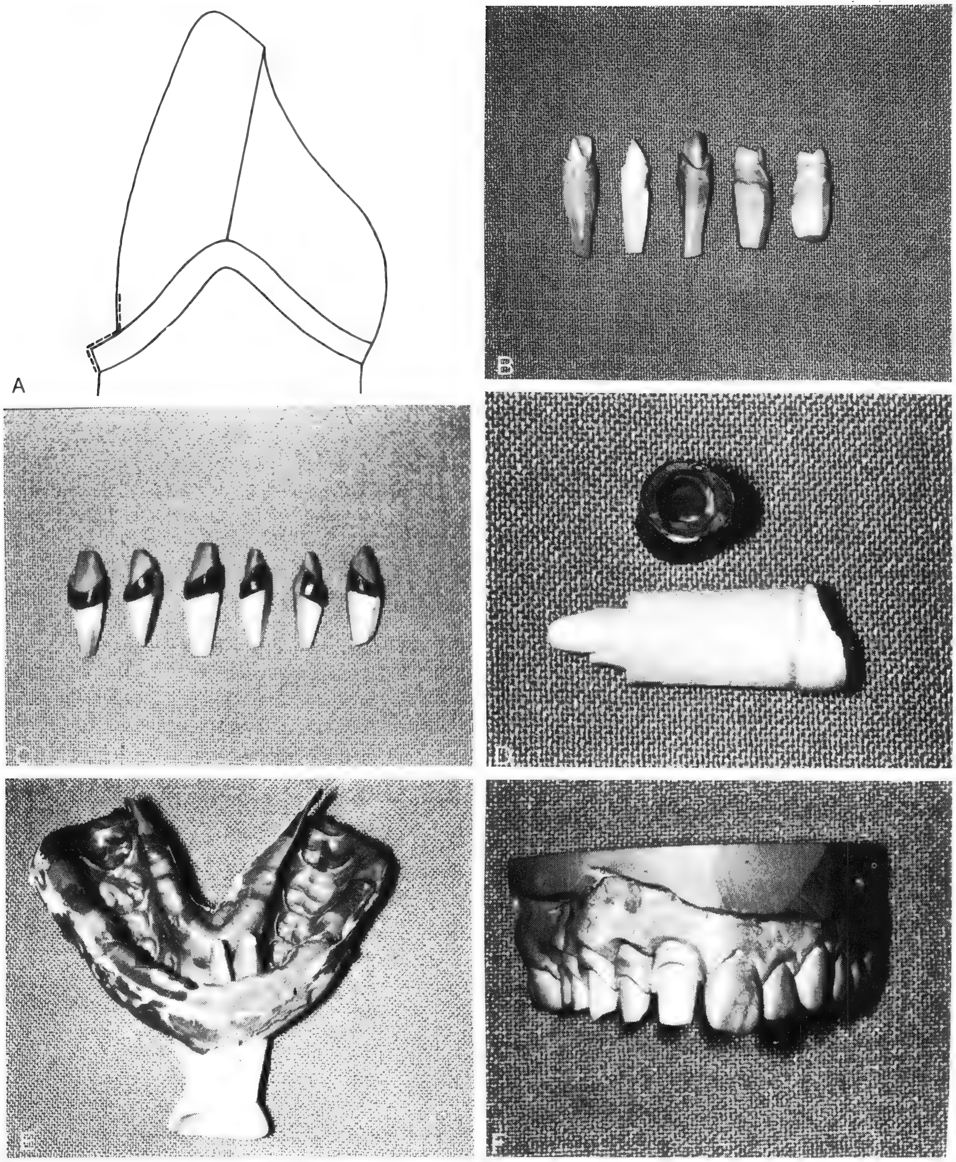


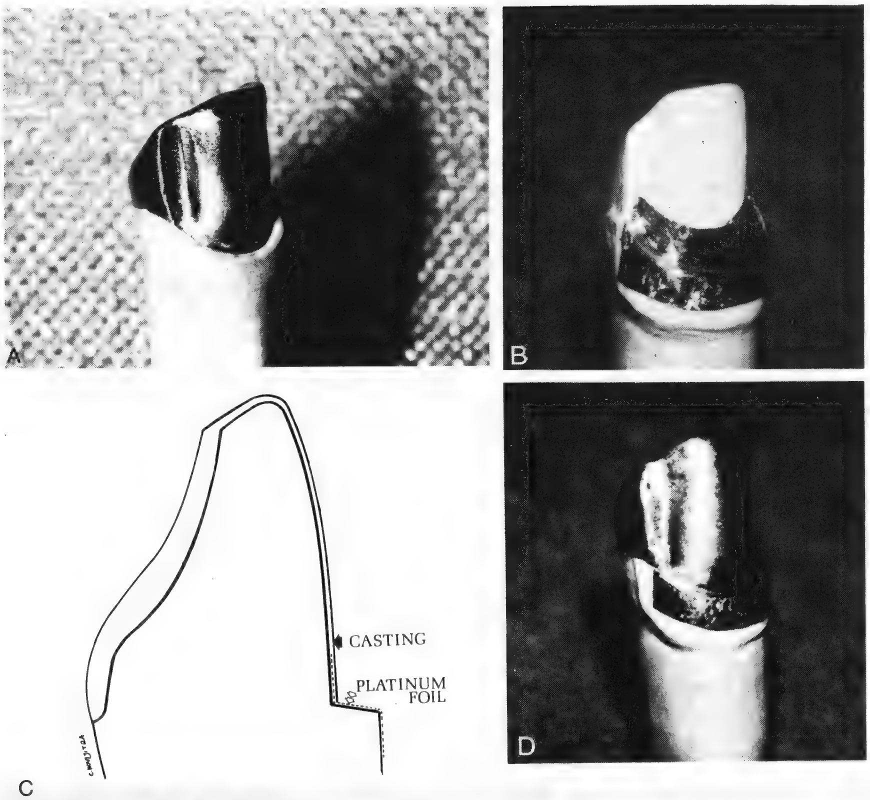
FIGURE 22–49 Fabricating Secondary Dies and Working Cast
A, Diagram showing platinum foil locked into cervical undercuts on primary die.
B, Primary dies.
C, Primary dies blocked out with wax.
D, Secondary die formed in stone from tube impression.
E, A tapered root has been formed on secondary dies. They have been inserted into mandibular full arch impression, fixed in position with sticky wax, and lubricated with petroleum jelly.
F, Full arch maxillary working cast with secondary dies in place.

Foil Application

Platinum foil, 0.001 inch in thickness, is intimately adapted to the facial aspect of the die. Some individuals prefer to use 0.0005-inch platinum foil. The foil should extend apically approximately 2 mm beyond the shoulder. The foil is trimmed so that it extends 2 mm incisally along the axial pulpal wall of the die. The foil should terminate interproximally at the point at which the shoulder becomes a chamfer (Fig. 22–50B). The casting is then seated over the adapted matrix (Fig. 22–50C,D). To ensure full seating of the casting, it usually is necessary to relieve the casting internally in the region in which the platinum foil and the casting overlap.

Foil Attachment by Welding

The foil is then attached to the casting on the die with sticky wax. The casting and attached foil are removed from the die and placed in an orthodontic spot welder (Fig. 22–50E). The platinum foil is electrowelded to the casting at spots approximately 1.5 to 2 mm apart. The



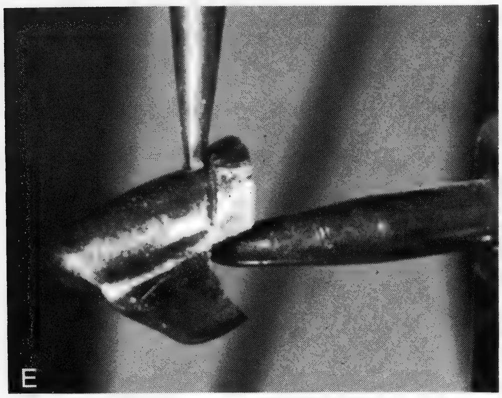


FIGURE 22–50 Attaching Platinum Foil Matrix to Casting

A, Finished casting without facial cervical collar.
B, Foil matrix adapted.
C, Diagram showing relationship of platinum foil to casting.
D, Casting seated over foil.
E, Casting and foil held between electrodes of welder.

heat-selector control of the spot welder should be placed on the "heavy" setting. For gold-platinum-palladium and gold-palladium alloys of 0.3-mm metal thickness, delivery of three impulses produces a sufficiently strong spot weld. Additional pulsations may be necessary to weld thicker metal. The spot welds provide an attachment of the foil to the casting that does not separate during firing procedures. The casting with attached foil is cleaned as usual prior to the application of porcelain.

Other Methods of Foil Attachment

Other procedures have been used to attach the foil matrix to the casting in order to avoid the spot welding process. One is to glue the matrix to the casting with a cyanoacrylate adhesive and then to apply and fire the opaque porcelain. The cyanoacrylate bond is destroyed during the opaque firing but is replaced by the bond between the opaque porcelain and the two metals. Extreme care must be exercised during subsequent handling, since the matrix is being held only by the small amount of opaque porcelain that has fused to it.

Another alternative to spot welding is available. A special pure gold powder is mixed with its supplied liquid to a creamy consistency and applied to the junction of the casting and foil. After the gold paste has dried, cyanoacrylate adhesive is applied over it so the casting and attached matrix can be removed intact from the die. The casting is then fired in an oven with the melting gold powder creating a soldered union between the casting and the matrix. With the spot welding technique, and sometimes when using cyanoacrylate

adhesive, porcelain particles penetrate between the casting and the matrix during condensation. When fired, the porcelain attempts to assume a spherical form that in turn distorts the alignment of the foil with the casting. The soldered connection of the matrix to the casting avoids this problem entirely.

The authors prefer to spot weld the matrix to the casting because the strong union cannot change during handling or firing procedures. However, subsequent soldering of the matrix to the casting is also recommended to prevent porcelain from entering between the casting and the foil.

The combined techniques of spot welding and soldering involve the following sequence: (1) spot welding the matrix, (2) ultrasonically cleaning the casting, and (3) applying the gold paste and subjecting the casting to the usual decontamination and oxidation cycle, which fuses the paste and creates the soldered connection (Fig. 22–51).

Porcelain Application

The opaque porcelain is applied so that it masks the metal-ceramic alloy but does not extend excessively far onto the platinum foil matrix. The assembly is then fired in the usual manner (Fig. 22–52A). The casting is replaced on the die, and the foil is readapted to the facial margin prior to the buildup of dentin and enamel porcelains in order to enhance the final fit of the restoration.

A thin layer of separating varnish* is applied to the foil extending over the margin. The varnish prevents porcelain from adhering to the foil during firing. The crown form is then established, and the porcelain is condensed directly against the varnished platinum foil margin. When the porcelain is fired, a cervical ditch forms as a result of porcelain shrinkage (Fig. 22–52B). An alternative is to build up the crown with dentin and enamel porcelain and mechanically create a ditch between the platinum foil and the porcelain with a sharp bladed instrument.

The fired and ditched restoration is reseated on the die after the initial firing of the dentin and enamel for the final adaptation of the platinum foil to the facial cervical margin. The cervical ditch is filled with porcelain, and the restoration is fired. It may be necessary to add porcelain to the cervical ditch a second time to completely fill it.

The facial margin is finished on the die in the same manner as described for the jacket crown, with the same instruments (Fig. 22–52C,D). Contouring of the remaining porcelain and occlusal refinement is completed using the mounted working cast.

The restoration is placed in the mouth for final shaping and staining procedures. The matrix should remain

*Vita Separator, Vident, Baldwin Park, CA 91706.

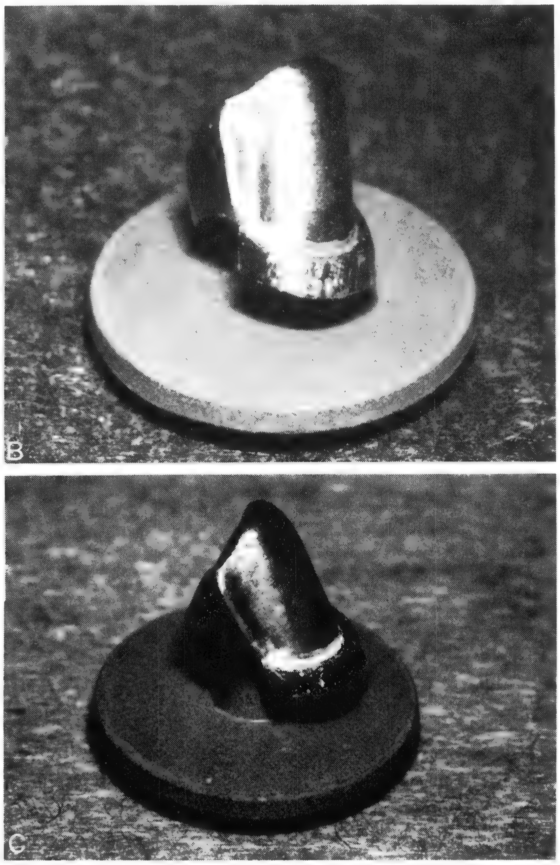


FIGURE 22–51 Soldering the Matrix to the Casting

A, Spectra-seal gold soldering kit.
B, Paste applied at junction of foil and casting.
C, Oxidized casting and completed solder connection.

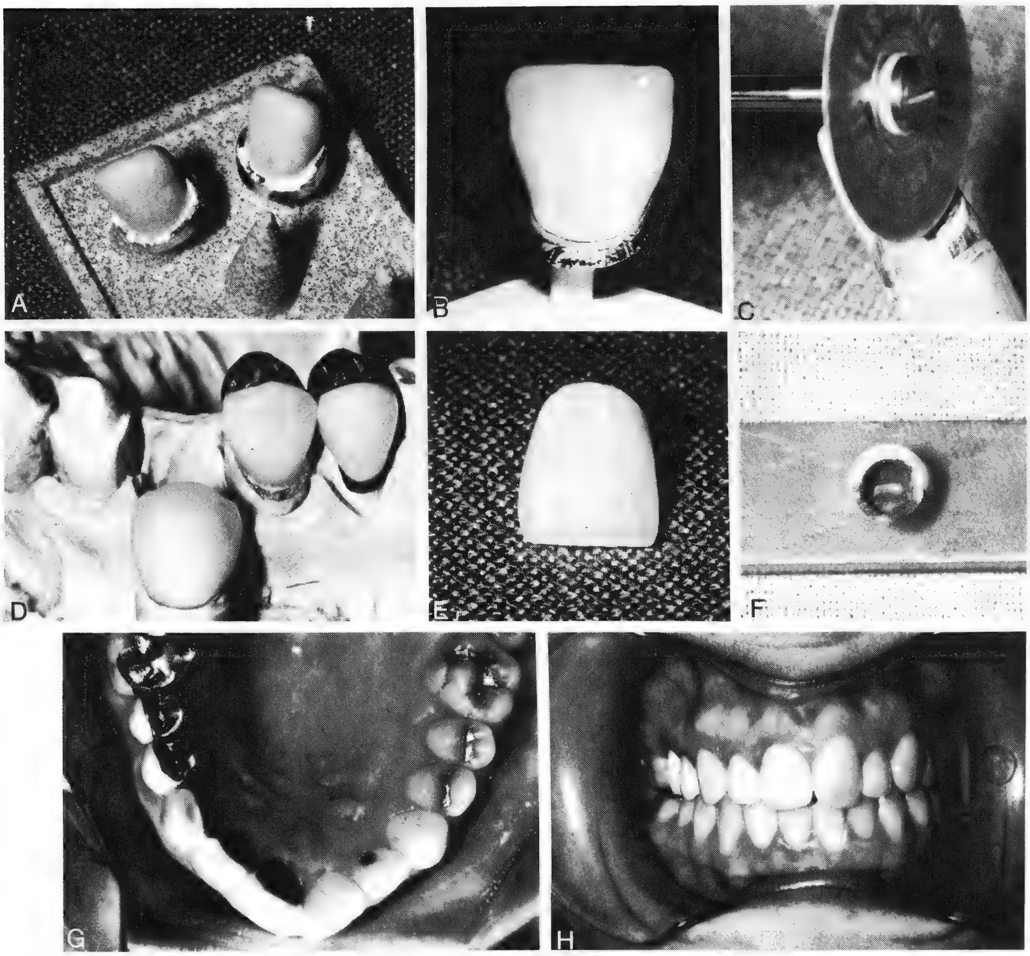


FIGURE 22–52 Porcelain Application and Finishing

A, Opaque porcelain fired.
B, Cervical ditch formed after initial firing of dentin and enamel porcelains.
C, Excess cervical porcelain being removed and restoration marginated using a diamond disc.
D, Three restorations on secondary working cast. The canine has been marginated.
E, Glazed crown with matrix in position.
F, Matrix removed.
G, Mirror view of cemented restorations.
H, Facial view.

attached to the restoration until it is glazed, since rounding of the margin occurs in the absence of platinum foil (Fig. 22–52E). After glazing, the platinum foil is removed, and the casting is polished (Fig. 22–52F). The restoration is then ready to be cemented (Fig. 22–52G,H).

Direct Lift-Off

A recently developed technique of fabricating collarless metal-ceramic crowns involves condensing porcelain directly against the die shoulder after it has been coated with an agent that prevents the porcelain from adhering to the stone die. This allows the casting, together with condensed porcelain, to be lifted off the die and fired without disturbing the porcelain.

The clinical and laboratory procedures are as follows:

1. The tooth is prepared as usual, and the impression is poured in stone to obtain a die and cast. Since porcelain is lifted directly off the die and no platinum foil extends cervically to the margin, there is no need to produce a die with the cervical undercut blocked out.
2. A casting is fabricated without a collar, and opaque porcelain is fired over the area to be veneered.
3. The shoulder of the die is coated with a thin layer of cyanoacrylate adhesive or a commercially manufactured sealing agent* and allowed to completely dry (Fig. 22–53A,B). When properly applied, the thickness of the sealant is about 5 μm and thus has little effect on the fit of the final restoration (Fig. 22–53C). A very thin film of releasing agent is applied over the sealed area, and the opaqued casting is seated on the die (Fig. 22–53D).

*Cerama Seal, Belle de St. Claire, Van Nuys CA 91406.

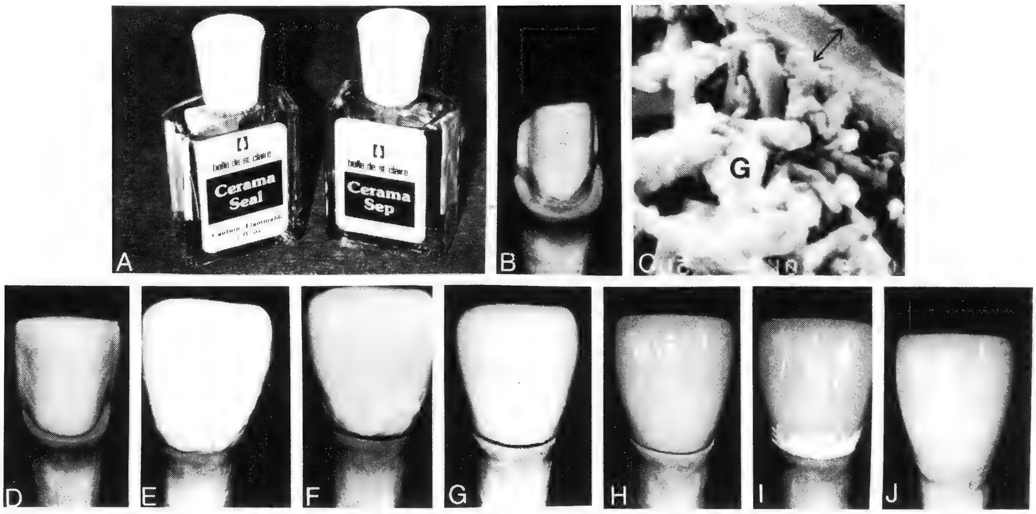


FIGURE 22–53 Direct Lift-Off Technique

A, Sealing and separating agents.
B, Sealer applied to die.
C, Scanning electron micrograph of one layer sealant applied to die, ×2300. Arrow shows sealant thickness and (G) shows gypsum die margin.
D, Separating agent applied and opaqued casting seated on die.
E, Full contour established.
F, Casting being removed.
G, Porcelain fired.
H, Glazed restoration.
I, Crown seated with correction porcelain at margin.
J, Finished restoration.

4. The desired contour is established with dentin and enamel porcelains (Fig. 22–53E). The porcelain is condensed directly against the margin, and the casting is lifted off the die (Fig. 22–53F). The bulk of porcelain at the margin generally allows complete separation of the marginal porcelain. When the porcelain is fired and shrinks, a definite marginal opening is formed (Fig. 22–53G).

   After firing, the casting is reseated on the die to which a thin layer of releasing agent has been reapplied. Additional dentin porcelain is vibrated into the marginal opening and condensed. If only a small marginal opening is present, difficulty may be encountered in getting the porcelain to completely fill the opening. Also, on removal, the relatively small amount of porcelain may attach itself to the die instead of to the previously fired porcelain, so that the process must be repeated. The restoration is removed from the die, and the porcelain is fired. The marginal opening should now be very small but will still not be acceptable. The restoration is then shaped, stained, and glazed (Fig. 22–53H).
5. The final step is to eliminate the marginal deficiency by using correction porcelain. The die is relubricated with the separating material. A special porcelain that fuses at a lower temperature and is designed especially for correcting small defects is used for the final marginal adaptation. The correction powder can be used alone, but some individuals prefer to mix it with dentin porcelain in the ratio of one to three. Use of the mixture helps eliminate the discernible cervical color change that can occur when correction powder is used alone. In order to give the porcelain powder the necessary body, it is moistened with the more viscous liquid supplied with stain kits.

   The mixed porcelain is applied to the margin of the crown, and the restoration is reseated on the die with a twisting motion to expel excess porcelain (Fig. 22–53I). The remainder is condensed. The porcelain quite often gets under the casting with this technique and detrimentally affects the fit of the metal so that the process must be repeated.

   To avoid this problem, the correction porcelain can be added to the restoration while it is seated on the die. This is also difficult because porcelain does not easily flow into the small marginal gap and frequently remains attached to the die when the restoration is removed. However, with perseverance, a satisfactory result can be obtained. The correction porcelain is fired in air according to the manufacturer's instructions. The marginal area is then smoothed, and the restoration is finished by using rubber porcelain polishing instruments (Fig. 22–53J). Air-fired polished porcelain is rougher than glazed porcelain, and some individuals prefer the application of an applied overglaze to attain a smooth surface. However, care must be exercised in firing the applied glaze, since too high a temperature can cause rounding of the margin.

The marginal discrepancy can also be corrected by using a porcelain-wax combination. The porcelain powder is mixed with wax* in the ratio of 6:1 (Fig. 22–54).

Another direct lift-off technique involves first apply-

*Plastodent U, Degussa Corporation, Placenta, CA 92670.

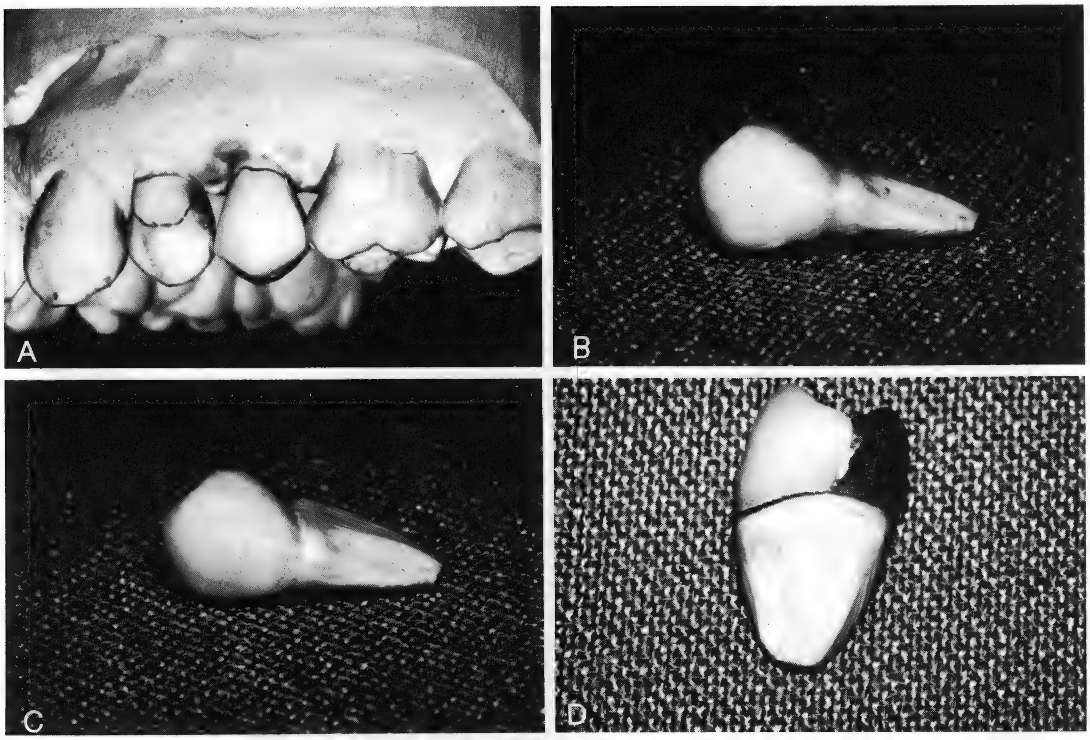


FIGURE 22–54 Porcelain-Wax Lift-Off Technique

A, Maxillary premolar after initial firing.
B, Porcelain-wax composite material made to flow into marginal defect with hot wax instrument.
C, Margin refined by carving.
D, Crown being lifted off die.

ing and firing porcelain to only the marginal area. The porcelain used for this process is either the usual opaque porcelain or a mixture of two-thirds opaque porcelain and one-third aluminous core porcelain. The addition of the aluminous porcelain contributes to the stability of the margin, since this material fuses at a higher temperature and is more resistant to pyroplastic flow during subsequent firing cycles. Commercially manufactured shoulder porcelains designed for this technique are also available, which provide a good color blend with surrounding dentin porcelain. The shoulder porcelain is applied so it extends to the margin, is condensed on the die, and then lifted off with the casting. The porcelain is fired, and the casting is returned to the die for the application of dentin and enamel porcelains, which are applied and fired as usual.

The direct lift-off techniques produce restorations with shoulder adaptation similar to that obtained with the platinum foil technique. However, slightly greater rounding of the cavosurface margin usually is present (Fig. 22–55).

Casting Directly to a Platinum Foil Matrix

This technique was the first one developed. It involves the formation of a partial platinum foil matrix covering only the facial shoulder finish line. A wax pattern is formed over the matrix, and metal is cast directly to the platinum foil. Porcelain is then applied, and the restoration is finished as usual.

Refractory Die Technique

A special refractory material is poured into an impression of the prepared tooth so that the die obtained is not destroyed by the porcelain firing temperatures. The refractory die allows porcelain to be fired directly against its surface, after it has been treated according to the recommendations of the manufacturer of the die material.

Opaque porcelain is applied and fired on a casting that has been fabricated without a faciocervical metal

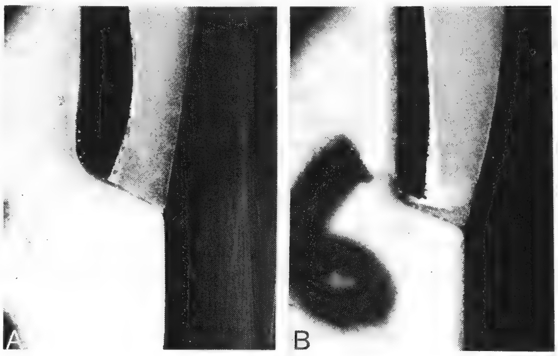


FIGURE 22–55

A, Cross section of collarless metal-ceramic crown using platinum foil matrix.
B, Cross section of collarless metal-ceramic crown using direct lift-off technique.

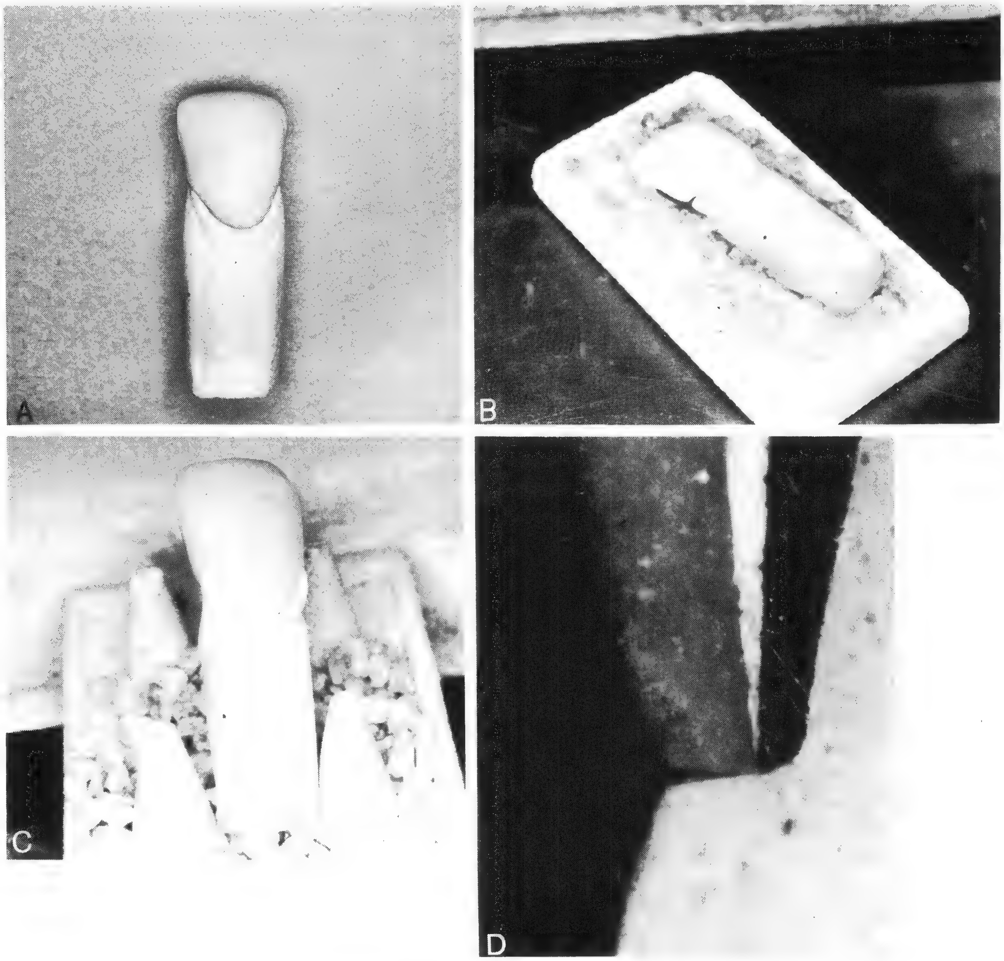


FIGURE 22–56 Refractory Die Technique

A, Opaqued casting seated on refractory die.
B, Dentin and enamel porcelain applied.
C, Additional porcelain added to margin.
D, Cross sections of typical collarless metal-ceramic crown fabricated using refractory die.

collar. The casting is seated on the refractory die (Fig. 22–56A), and dentin and enamel porcelains are applied. The porcelain is condensed directly against the shoulder of the die. The die, with its casting and condensed porcelain, is placed on a firing tray, dried, and fired as usual (Fig. 22–56B). A marginal opening between the porcelain and die develops after the initial firing. Additional porcelain is added to compensate for this firing shrinkage and to provide for a slight excess of material after firing so that the restoration can be shaped to the desired form (Fig. 22–56C).

The margins are refined, the final shape is achieved, and the porcelain is glazed. The die material is then fractured away from the porcelain. This technique usually produces inferior marginal adaptation. The margin is also more rounded and rough (Fig. 22–56D).

Conclusion

From the previous discussion, it is easy to see that no ideal technique has been developed for fabricating collarless metal-ceramic restorations. While acceptable restorations can be fabricated by several different methods, the authors prefer the well fitting predictably sharp margins obtained through the use of platinum foil.

23

Metal-Ceramic Fixed Partial Dentures

Fixed partial denture tooth preparations utilize the same reduction depths and form as described for a single restoration with 3 to 5 degrees of taper developed between the abutment teeth (Fig. 23–1).

The main differences between single metal-ceramic restorations and fixed partial dentures relate to pontic design and assembly technique. Some porcelain application and contouring variations are also necessary owing to the presence of pontics.

METAL-CERAMIC PONTICS

Developing Pontic Wax Patterns

Full-contour wax patterns are developed for the abutment retainers as previously described, and the edentulous ridge of the working cast is coated with die lubricant. A pontic is formed by molding softened wax into roughly the desired form and pressing the wax into intimate ridge contact (Fig. 23–2A). When the wax hardens, the pontic is removed from the cast so that the quality of ridge adaptation can be verified. Excess wax is carved away, and additional wax is added until the final contour is achieved (Fig. 23–2B).

The visible location of anterior metal-ceramic pontics requires normal tooth form and dimensions from a facial view. However, the area of ridge contact is reduced lingually, and the lingual embrasures are opened to facilitate access with oral hygiene aids. Wax connectors are then formed between the individual parts to stabilize their position for subsequent cutback procedures.

When the full-contour wax patterns are completed, a facial impression is obtained by using an elastomeric putty impression material. A cast is then poured, which serves as a valuable aid for locating the embrasures in the fused porcelain and shaping each tooth according to a predetermined plan (Fig. 23–3).

Wax Pattern Cutback for Veneering

Facial Veneer Cutback

Depending on whether an anterior or posterior fixed partial denture is being fabricated, the wax patterns are reduced incisally or occlusally so that adequate translucency is present in the incisal edge or facial cusp (Fig. 23–4A,B). The termination of the cutback is kept 2 mm away from centric occlusal contacts or extended so that

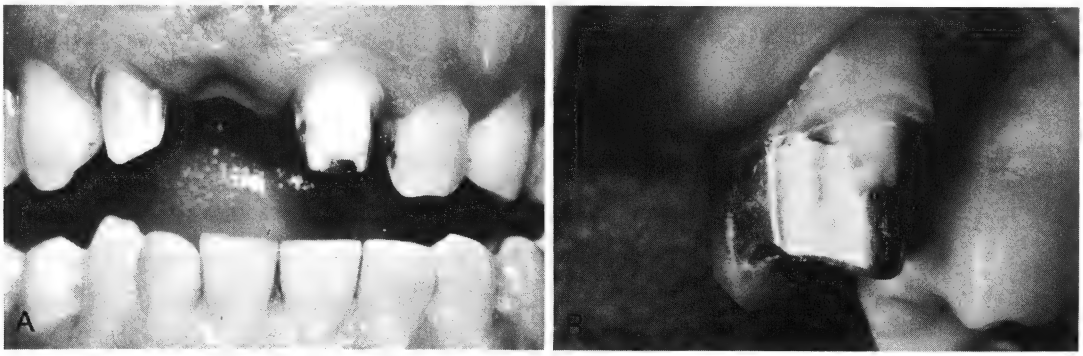


FIGURE 23–1

A, Metal-ceramic preparations for anterior prosthesis.
B, Maxillary premolar preparation.

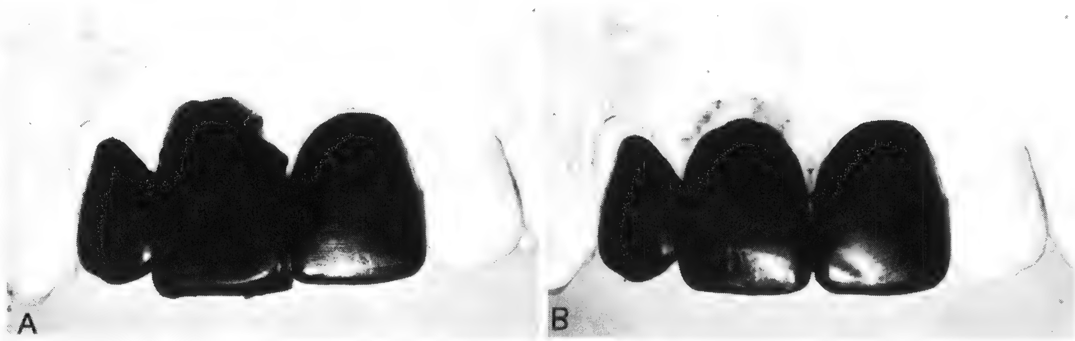


FIGURE 23–2 Developing Full-Contour Pontic Patterns

A, A layer of wax has been made to flow over a lubricated ridge, and a softened stick of wax has been pressed into contact with the ridge. Wax has been made to flow cervically to complete ridge adaptation.
B, Pontic carved to desired form.

the contacts occur on porcelain. The usual obtuse angle is formed between the reduced incisal surface and the intact lingual surface of the wax pattern. The facial surface is uniformly reduced on the abutment retainers and pontics to leave 0.3 to 0.5 mm of wax thickness on the retainer patterns (Fig. 23–4C,D). The previously obtained facial impression can then be repositioned on the cast to ensure that uniform and adequate facial reduction has been achieved.

The wax connectors are reduced facially so that porcelain can cover and mask the metal, while sufficient wax thickness is maintained to provide adequate strength in the final casting. Cervical to the connectors, the cutback is extended lingually so metal is not visible in the cervical embrasures of the final restoration. On proximal surfaces not involving a connector, the cutback is extended at least 1 mm lingual to the proximal contact.

Cervically, a 0.3- to 0.5-mm thick collar is retained on the facial surface of the abutment wax patterns. On pontic wax patterns, the facial reduction is extended uniformly to the edentulous ridge without developing a

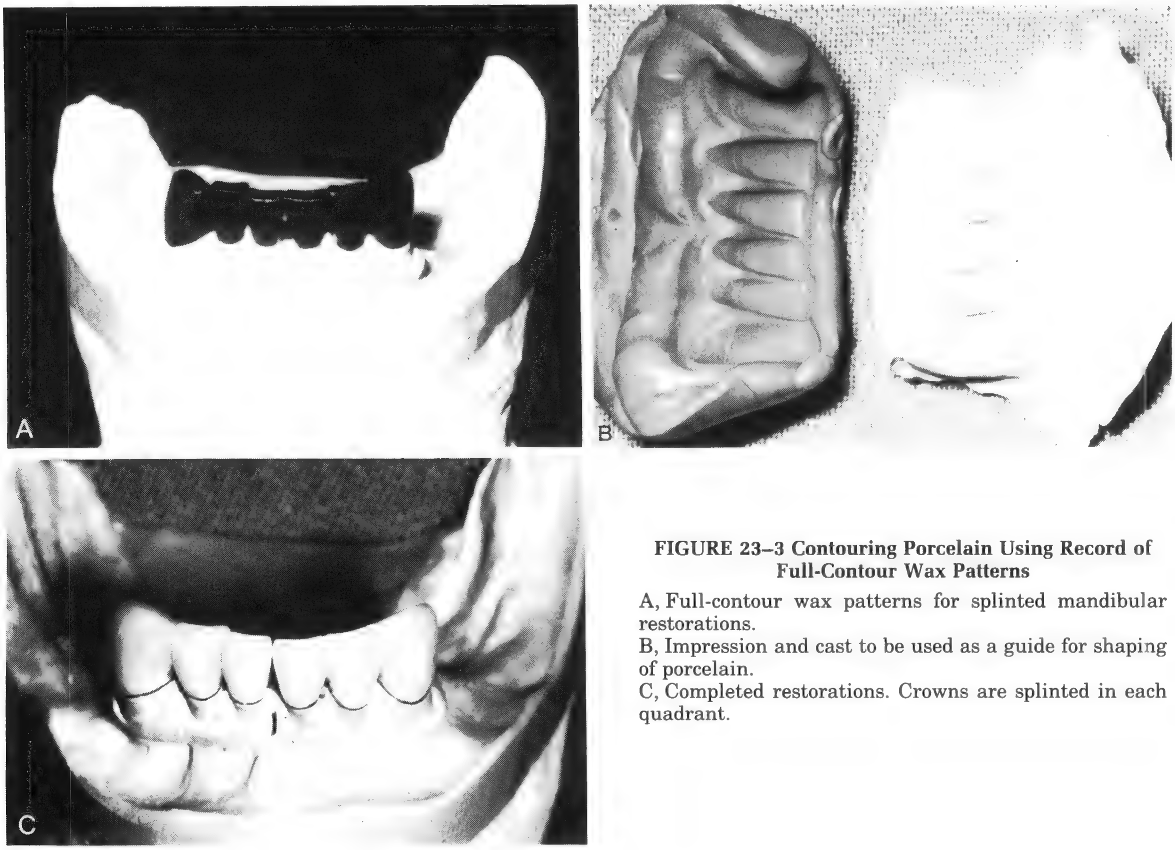


FIGURE 23–3 Contouring Porcelain Using Record of Full-Contour Wax Patterns

A, Full-contour wax patterns for splinted mandibular restorations.
B, Impression and cast to be used as a guide for shaping of porcelain.
C, Completed restorations. Crowns are splinted in each quadrant.

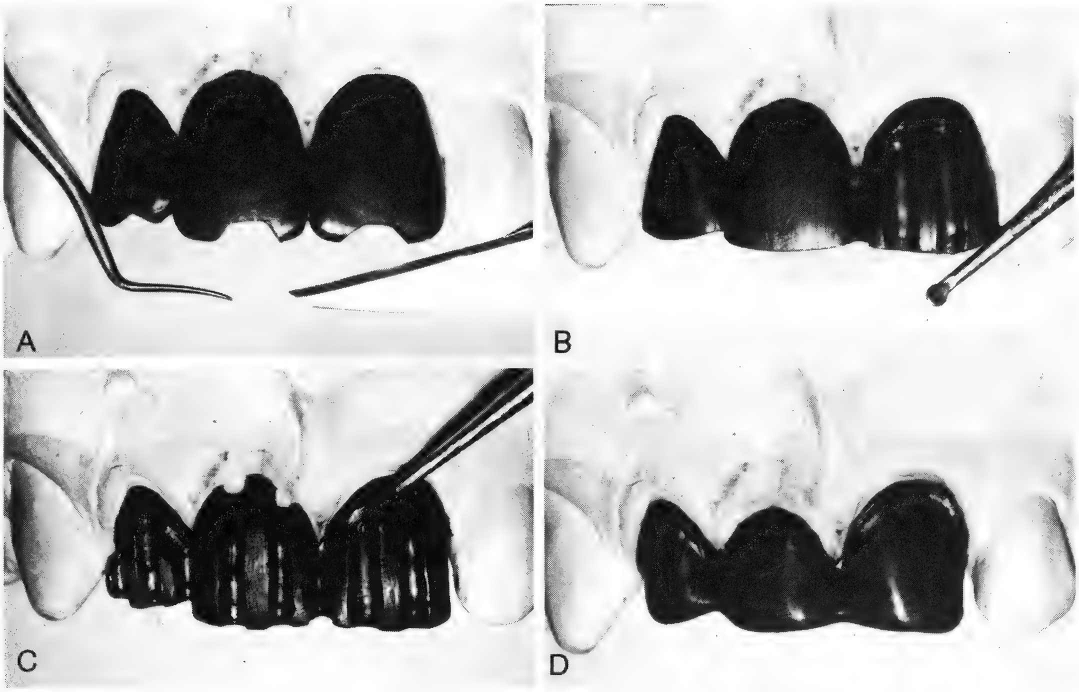


FIGURE 23–4 Wax Pattern Cutback for Facial Porcelain Veneer

A, Incisal edges partially reduced. A scalpel blade or PKT number 4 wax carving instrument can be used.
B, Incisal edges reduced and facial depth cuts placed in wax using cleoid-discoid instrument.
C, Facial surface being reduced to level of depth cut while cervical collar is retained.
D, Completed cutback.

cervical collar of wax. Wax contact with the ridge is maintained lingually.

Alternatively, the cervical portion of the pontic can be uniformly reduced so the ridge contact is formed entirely of porcelain. An advantage of this process is that only glazed porcelain contacts the tissue. However, it is easier to develop the correct porcelain form when metal is available lingually to serve as a contour guide. It is also more difficult to achieve good condensation when porcelain covers the entire ridge.

All internal angles are rounded, as usual, over the veneering areas.

Full Porcelain Coverage Cutback

The retainer wax patterns are reduced to the same form that is used with single full porcelain coverage restorations. Pontics are also uniformly reduced, allowing porcelain to cover all but the lingual one-half of the ridge lap. A collar, 3 mm in height, is formed across the lingual surface of all the retainers and pontics to provide the needed prosthesis rigidity (Fig. 23–5A, B, C). The collar possesses a scalloped form, curving away from the gingiva as the connectors are approached and then dipping cervically in the center of the lingual surface. The scalloped form allows adequately sized connectors to be developed that are enough out of contact with the gingival tissue that cervical embrasures are formed that are readily cleansed.

To ensure a complete casting with full porcelain coverage retainers, it is best to flow a bead of wax over the thin facial and occlusal surfaces (Fig. 23–5D).

UNITS TO BE CAST TOGETHER

After the wax patterns have been cut back and smoothed, a decision must be made as to how many parts of the prosthesis are to be cast as one unit. While acceptable marginal adaptation can be achieved by a careful experienced individual, many of the restorations cast in one piece lack adequate marginal fit and cervical contour. Technicians often cast prostheses in one piece to avoid the soldering process, which can be difficult with the thinner frameworks encountered on metal-ceramic restorations. However, the most accurate method is to cast individual sections of the prosthesis and to unite the parts with solder. Assembly of the parts by soldering is easier, however, if a pontic is cast together with an adjacent retainer.

When a restoration is cast as individual parts and then assembled later, one or more of the previously established wax connectors must be separated. This is easily accomplished by using unwaxed dental floss in a faciolingual sawing motion to produce a small clean cut, which separates the parts. Additional wax is added proximally to provide excess metal so the desired gap distance can be established during metal finishing. The individual parts are invested and cast as usual.

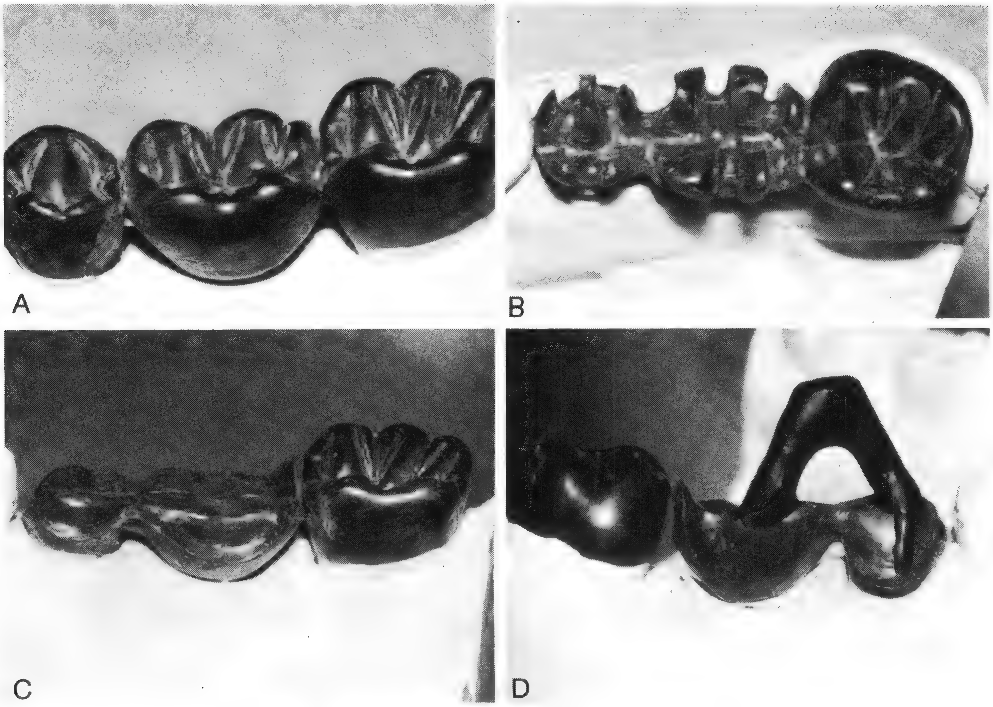


FIGURE 23–5 Full Porcelain Coverage Cutback

A, Full-contour wax patterns.
B, Depth cuts formed facially, occlusally, and lingually on second premolar and molar. Second molar is not visually accessible and will not be veneered with porcelain.
C, Lingual view of completed cutback. Distal aspect of molar projects occlusally to provide metal for postceramic solder connection to full cast crown on second molar.
D, Cutback viewed facially. A bead of wax has been applied to cover thin areas of the premolar, and sprue formers have been attached.

SPRUE FORMER ATTACHMENT TO MULTIPLE UNITS

Two different methods of sprue former attachment have been successfully used for casting of several units or an entire prosthesis as one piece. One technique is to attach a 10-gauge wax sprue former to each unit and to gently curve them toward the center of the prosthesis at which they are united with wax (Fig. 23–6).

The second technique is to attach sprue formers so they project straight from each pattern to a transversely oriented runner bar, which is thicker than the sprue formers. The runner bar is attached to the crucible former with additional sprue formers, which are larger in diameter than the runner bar (Fig. 23–7). Individuals who advocate this system believe the runner bar and larger number of sprue formers increase the rigidity of the assembly so that multiple units can be removed from the working cast with less wax distortion. They also believe that less distortion occurs in the casting as the alloy solidifies.

The margins of the retainer wax patterns are readapted and finalized as usual just prior to the investing procedure.

INVESTING, CASTING, AND FINISHING

Two and sometimes three connected units fit inside a small casting ring (1¼ inch diameter). Greater numbers of connected units require larger rings (1¾ inch and larger) and associated crucible formers. The ring is lined and the investment is handled in the customary manner. Care must be exercised when mixed investment is allowed to flow into the ring to avoid trapping of air around the larger number of sprue formers.

When the investment hardens, the crucible former is removed, and the casting machine is rebalanced to allow smooth spinning because of the greater weight of investment and alloy. Longer burnout times of 1 to 2 hours are required with larger rings of investment to allow complete wax elimination and the development of proper internal mold temperature. Casting procedures are the same except that a greater amount of alloy is required to cast multiple units.

The metal casting is finished with the usual instruments, and care is taken to ensure that no metal is visible in the cervical embrasures. If preceramic soldering is to be performed, the castings should not be finished to their final thickness and form. Maintaining the "as-

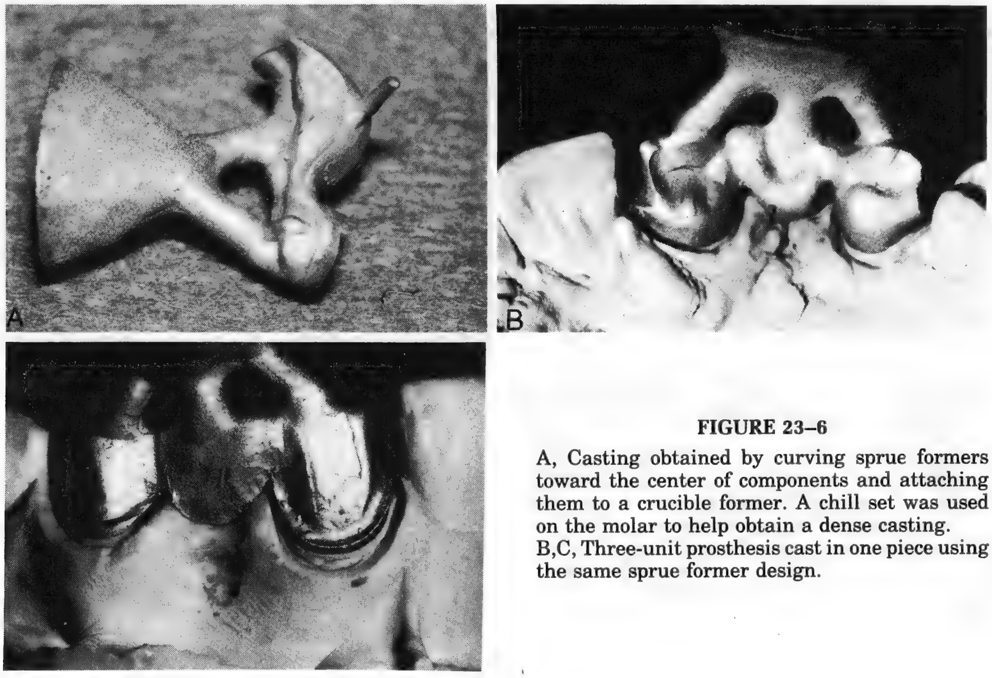


FIGURE 23–6
A, Casting obtained by curving sprue formers toward the center of components and attaching them to a crucible former. A chill set was used on the molar to help obtain a dense casting. B,C, Three-unit prosthesis cast in one piece using the same sprue former design.

cast" thickness can help prevent inadvertent melting or deformation of the thinner areas.

PRECERAMIC SOLDERING

Metal-ceramic restorations can be assembled prior to the application of porcelain (preceramic soldering) or after the porcelain has been finished and glazed (postceramic soldering). Preceramic soldering is often called *high fusing soldering* because the solder flows above the fusion temperature of the porcelain. Postceramic soldering is likewise called *low fusing soldering* because the solder flows below the porcelain fusion temperature. The postceramic soldering technique is discussed later in this chapter.

For preceramic soldering, the parts are assembled on the working cast with the same gap distance as for conventional soldering. The approximating surfaces should be polished to a clean satin finish. Preceramic solder is compositionally similar to the parent alloy and thus does not flow and spin as readily as conventional low fusing solders. For this reason, the parts should not be in contact with each other, since this can prevent a complete joint from being formed.

The index is obtained as usual, the parts are attached with sticky wax, and the index is boxed (Fig. 23–8). Conventional soldering investments do not withstand the elevated temperatures of preceramic soldering without cracking and breakdown. Soldering investments designed to withstand higher temperatures should be used, or a phosphate-bonded casting investment can be mixed with water and used as the soldering investment. The investment should completely encompass the casting margins and as much of the thin surfaces as possible so that they are protected from the high temperatures (Fig. 23–9). Preceramic solders may flow within 100° F of the alloy melting range, depending on the type of casting metal used.

The hardened investment assembly is cleaned of wax, and a special flux designed for preceramic soldering is applied to the joint area (Fig. 23–10A). The assembly is heated in an oven to 704° C (1300° F) and held there for at least 15 minutes to assure uniform heating. The heated assembly is then placed on a tripod stand with a Bunsen burner flame to provide heat from below. A gas-oxygen torch with a tip that produces a small flame is used to heat the assembly. The smaller flame allows the heat to be focused on the joint area with less chance of overheating other areas. The use of a large flame, such as the one used to melt metal-ceramic alloys for casting, is more likely to overheat the castings and inadvertently melt the prosthesis.

The assembly is uniformly heated until the castings begin to glow and then a section of solder, lightly coated with preceramic flux, is placed in physical contact with both parts. A little excess solder, beyond that needed to

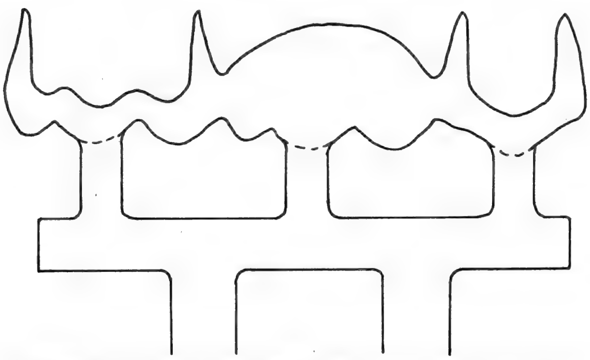


FIGURE 23–7 Runner bar design for casting multiple units.

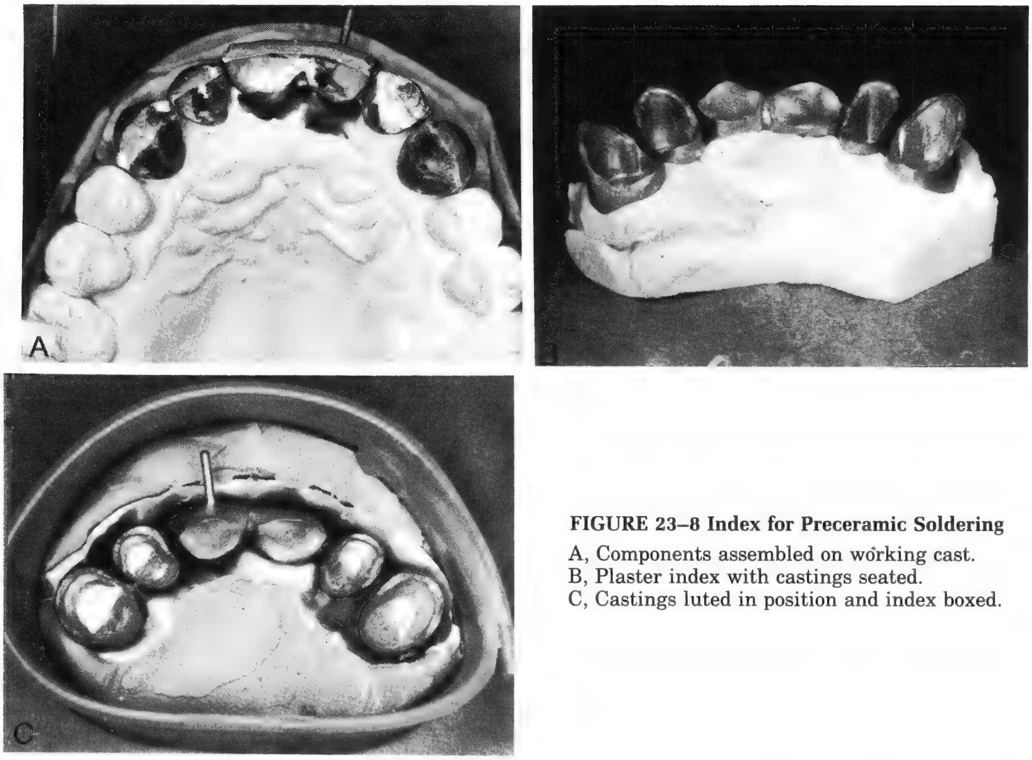


FIGURE 23–8 Index for Preceramic Soldering

A, Components assembled on working cast.
B, Plaster index with castings seated.
C, Castings luted in position and index boxed.

form the desired joint size, should be used, since preceramic solder does not flow as readily as conventional solders and is more likely to form an irregular joint requiring reshaping by grinding. The flame is briefly concentrated on the joint area until the solder slumps and fills the gap. Prolonged contact should be avoided, since the casting may melt or be distorted.

After cooling and devesting, the veneering area of the soldered prosthesis is finished and cleansed as usual in preparation for porcelain application (Fig. 23–10B).

FIRING TRAYS

All alloys undergo high-temperature distortion during the firing of porcelain. However, the magnitude of this distortion is not significant if adequate casting dimensions are maintained and the framework is properly supported by the firing tray.

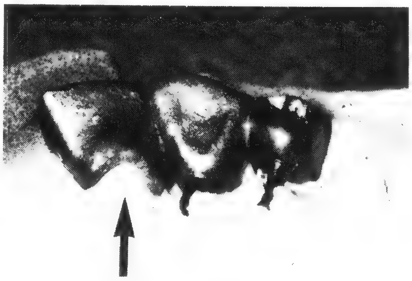


FIGURE 23–9 Preceramic solder joint completed. Note that the margin and part of the lingual surface melted (*arrow*) because the area was thin and not covered with investment.

Manufactured trays* are available with multiple posts that can be positioned at different intervals along the span length of the prosthesis to provide good support. Also, trays† are manufactured with support posts that swing from the side, allowing even greater adjustability (Fig. 23–11).

PORCELAIN APPLICATION FOR FACIALLY VENEERED PROSTHESES

The prosthesis is decontaminated and oxidized as usual. The application and firing of opaque porcelain follow. In order for the dentin porcelain to lift off the edentulous ridge of the working cast, two procedures are possible. The edentulous ridge can be coated with a sealing agent and a releasing agent can be applied, allowing porcelain to be condensed directly against the form of the ridge. The porcelain is then lifted off without disturbing the shape of the condensed porcelain.

Alternately, cigarette paper can be placed on the edentulous ridge and moistened, and dentin porcelain is applied directly on top of the paper. After the buildup is complete, the porcelain can be lifted off the cast and the paper peeled from the porcelain.

Mixed dentin porcelain is applied to one of the units until the desired oversized form is developed. The other

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*Vita Large Firing Tray G, Vident, Baldwin Park, CA 91706.
†Pegboard Sagger Tray, Dentsply International, York, PA 17404.

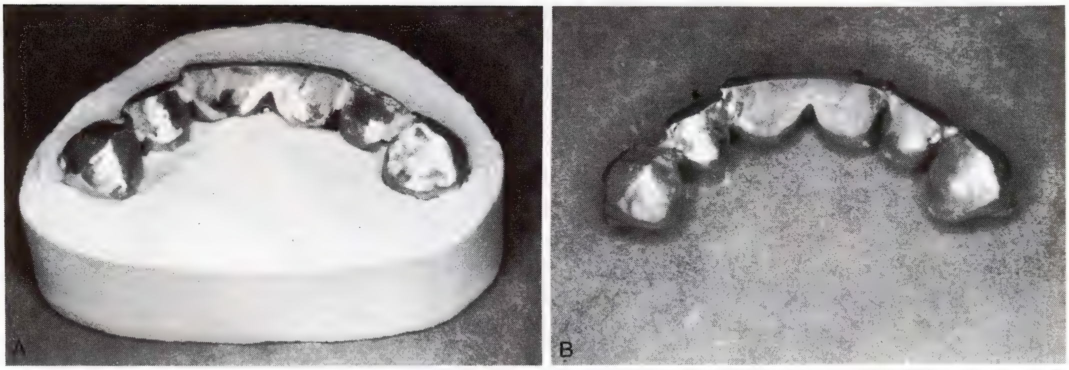


FIGURE 23–10 Preceramic Soldering

A, Soldering assembly cleaned and flux applied to joints.
B, Soldering completed and prosthesis devested.

units are then built up in the same manner until all the units are complete (Fig. 23–12A,B). A portion of the dentin porcelain is carved away wherever translucency is required, and enamel porcelain is added to reestablish the oversized form of the prosthesis (Fig. 23–12C,D). The porcelain is condensed, and separation cuts are made interproximally to produce individual units (Fig. 23–13A). The cut is produced with a thin-bladed sharp instrument and should extend close to the opaque layer. During firing, the separation allows the porcelain shrinkage to occur toward the center of each unit, opening up the proximal areas, which can easily be filled. Without separation, the firing shrinkage of the porcelain can cause greater amounts of metal framework distortion and shrinkage cracks can occur in undesirable locations (such as the center of the facial surface). These cracks are difficult to fill without being visually apparent in the final glazed porcelain.

The restoration is removed from the cast, the prosthesis is held firmly with hemostats, and additional

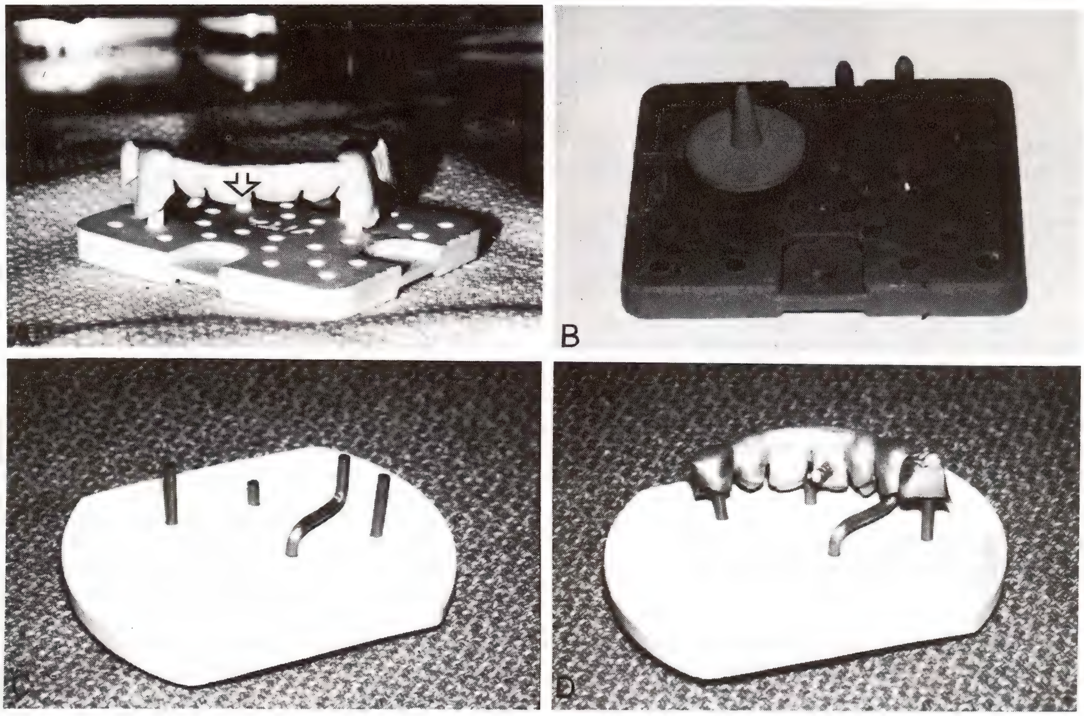


FIGURE 23–11 Firing Trays

A, Multiple post tray supporting an eight-unit prosthesis as opaque layer is drying. Note the small peg supporting the center of pontics.
B, A conical peg on the platform can be combined with pins in fixed positions.
C, Tray using fixed and swivelling metal pins.
D, Seven-unit framework supported using this system.

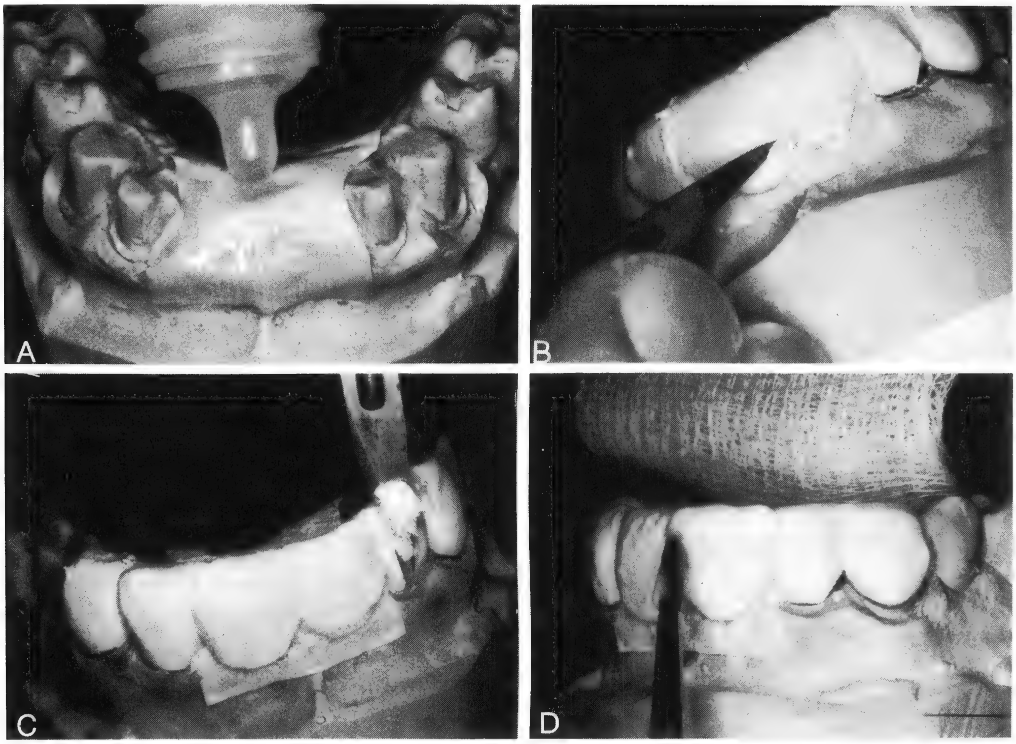


FIGURE 23–12 Dentin and Enamel Buildup on Cast

A, Cigarette paper applied to cast and wetted.
B, Dentin porcelain built to full contour and being carved proximally.
C, Cutback for incisal porcelain.
D, Incisal porcelain being applied.

condensation is performed (Fig. 23–13B). Some interproximal slumping is likely to occur and it is therefore necessary to redefine the separation cuts.

The prosthesis is placed on a firing tray and dried for 10 to 20 minutes, depending on the porcelain bulk. After firing, the interproximal embrasures are widely open and the pontic porcelain is out of contact with the edentulous ridge (Fig. 23–13C). Additional porcelain is added and fired to fill the interproximal areas and establish contact with the ridge (Fig. 23–13D,E). A third firing is often necessary to completely fill the interproximal areas and provide a slight cervical excess on the pontics so they can be ground to accurately fit the edentulous ridge (Fig. 23–13F).

PORCELAIN APPLICATION FOR FULL PORCELAIN COVERAGE PROSTHESES

Dentin porcelain is incrementally applied to the fired opaque porcelain until the axial contour is established. The cusps are then formed as cones and the articulator is closed to ensure proper interdigitation with the opposing teeth (Fig. 23–14A). Triangular ridges are established, fossae are located, and remaining areas are filled in with porcelain (Fig. 23–14B).

Dentin is carved away facially and over the marginal and triangular ridges in which translucency is needed, and enamel is applied (Fig. 23–14C,D). The porcelain is then condensed so grooves can be carved into the occlusal surface.

A PKT number 3 waxing instrument is used to carve the grooves (Fig. 23–15A). Then the carved areas are smoothed with a moistened brush (Fig. 23–15B,C). The porcelain is dried and fired as usual (Fig. 23–15D).

SHAPING AND GLAZING THE PORCELAIN

To allow complete seating on the working cast, interfering porcelain must first be reduced from the proximal contact areas and the ridge contacting aspect of the pontic (Fig. 23–16).

Next, a thin diamond disc is used to produce facial embrasures that give the illusion that individual teeth are present (Fig. 23–17). The location and angulation of the diamond cut is critical, since it determines the size and form of each tooth. The cast obtained from an impression of the full-contour wax patterns should be referred to, and measurements should be obtained that can be transferred to the prosthesis. Pencil marks are placed at the proper location and angulation, and shallow cuts are formed with the diamond disc. After the location of the cuts is verified visually, they are deepened to the desired depth of the facial embrasure. Some dentin porcelain should be retained over the opaque layer. If the separation cut is placed in the wrong area or if it is

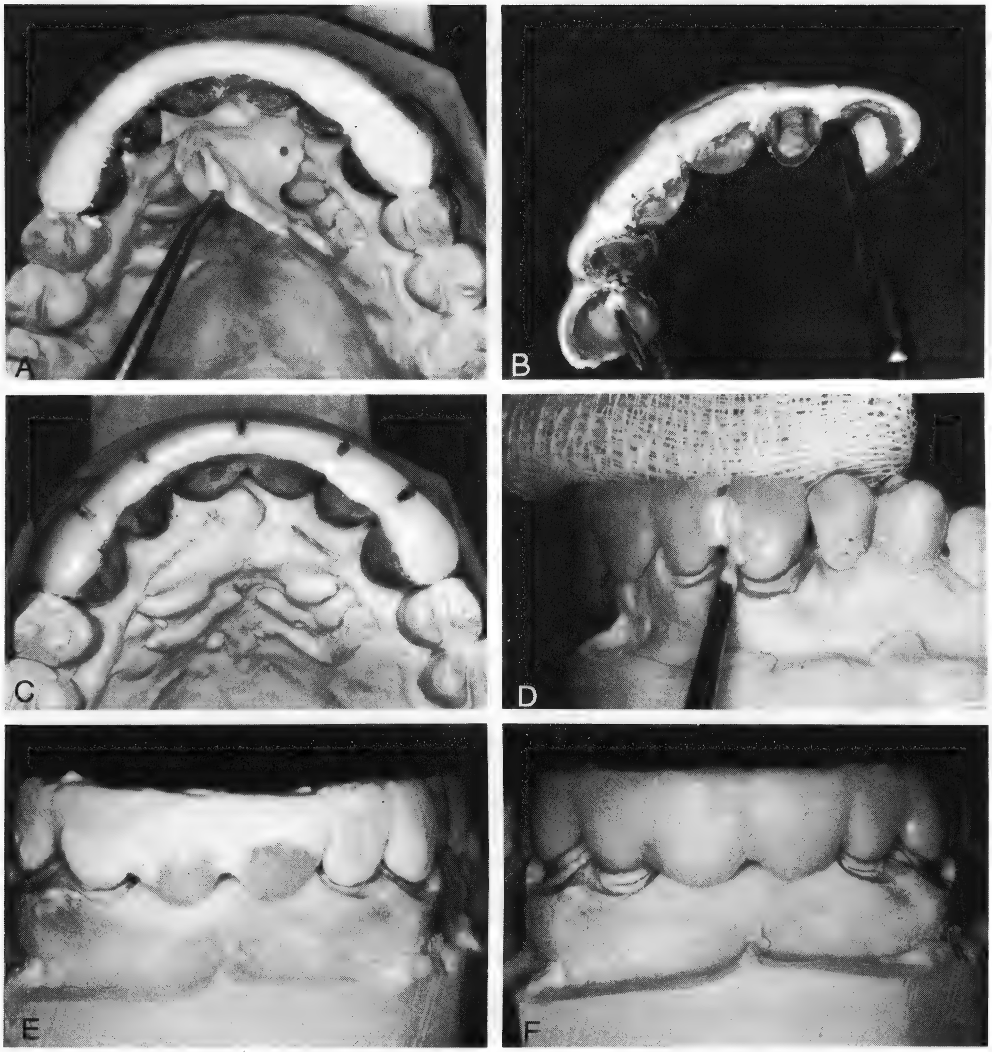


FIGURE 23–13 Removal, Initial Firing, and Firing of Additional Material

A, Porcelain condensed on cast and interproximal separation created. Paper is being lifted from the cast.
B, Excess porcelain being removed proximally.
C, Porcelain fired. Note that interproximal slits have opened.
D, Porcelain added interproximally.
E, Correction of deficient contours.
F, Porcelain fired. Excess material at proximal contacts and ridge lap prevents complete seating.

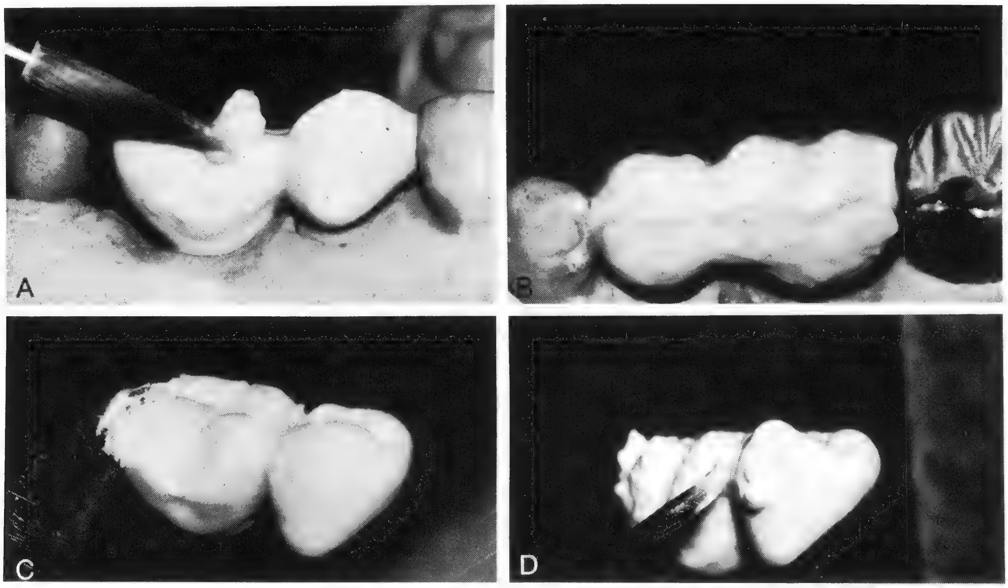


FIGURE 23–14 Full Porcelain Coverage Dentin Buildup and Enamel Application and Condensation

A, Mesiobuccal cusp of molar being formed.
B, Cusps, triangular ridges, and fossae formed.
C, Cutback for enamel porcelain.
D, Enamel being applied facially.

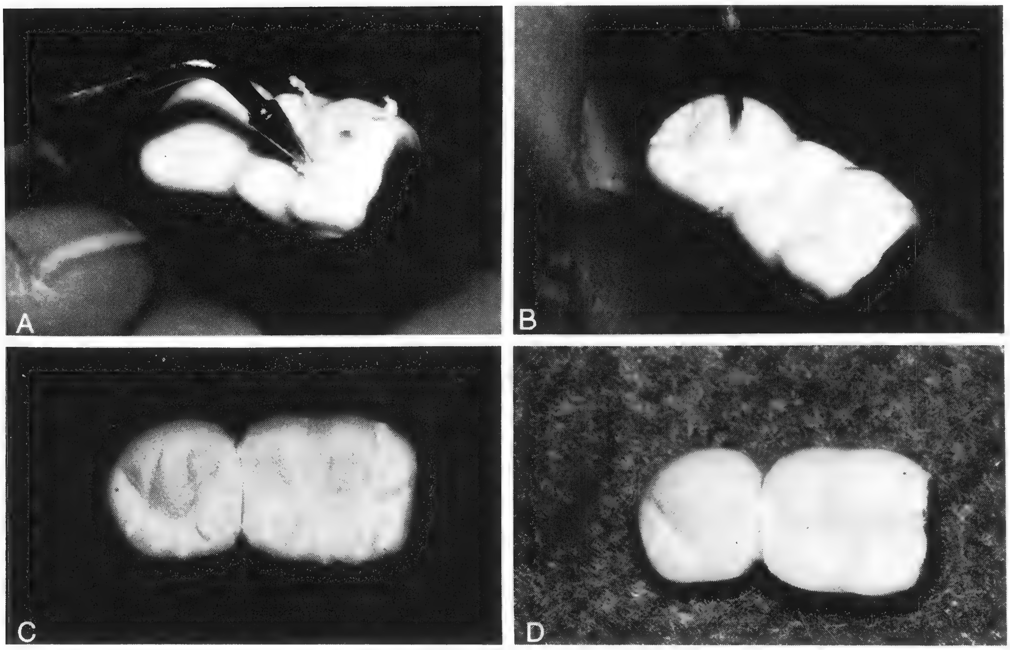


FIGURE 23–15 Carving Occlusal Anatomy and Firing

A, PKT number 3 wax carving instrument being used to form grooves.
B, Moistened brush smoothing carved surface.
C, Completed carving.
D, After firing.

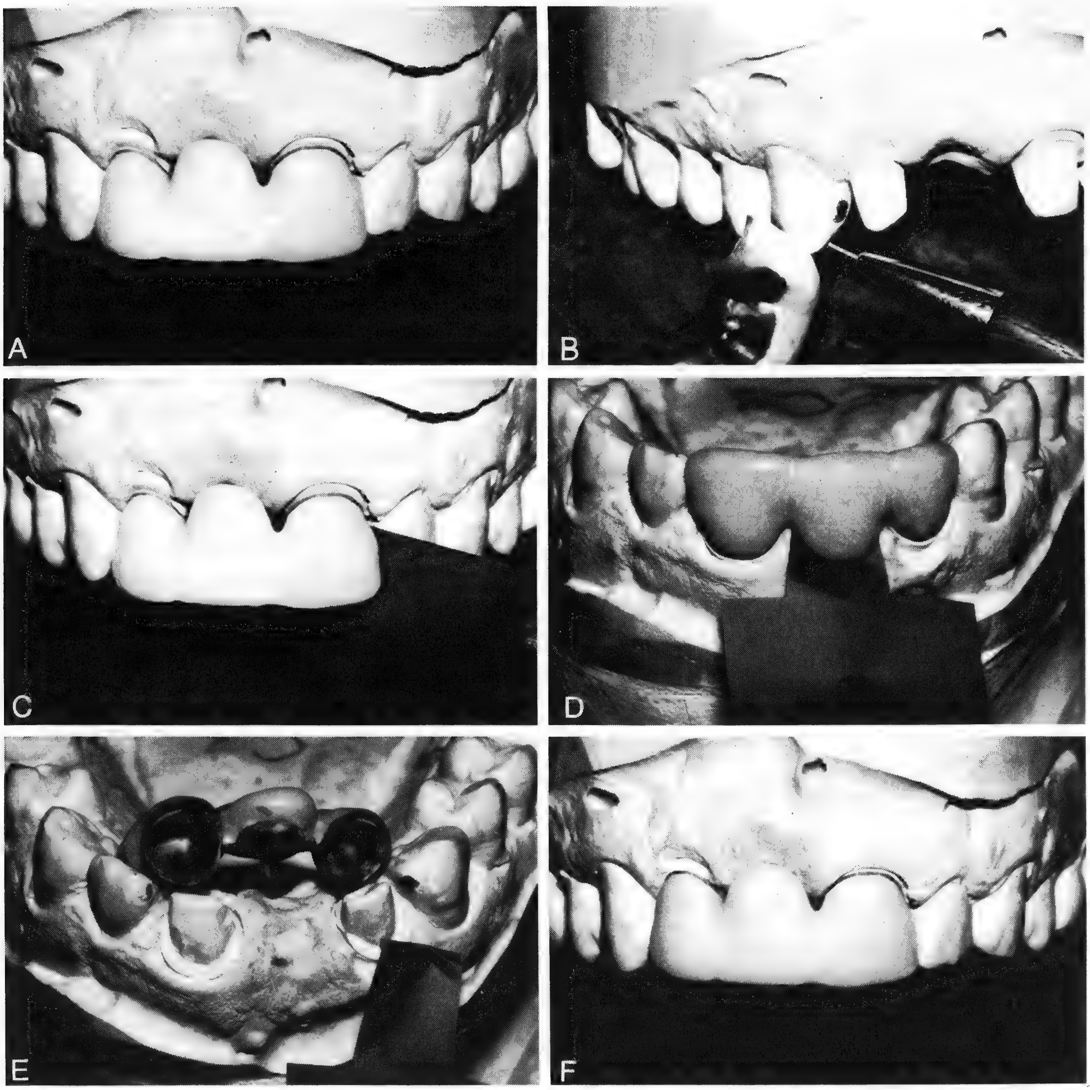


FIGURE 23–16 Contouring Porcelain to Obtain Complete Seating on Cast

A, Cervical aspect of pontic and proximal contact areas prevent seating of prosthesis.
B, Pencil mark placed proximally and transferred to porcelain to indicate area that needs adjustment.
C, Articulating paper being used proximally in place of pencil marking.
D, Articulating paper trimmed to fit under pontic.
E, Tapping on the prosthesis transfers the mark to the ridge contacting area that needs reduction.
F, Prosthesis adjusted so that complete seating is achieved.

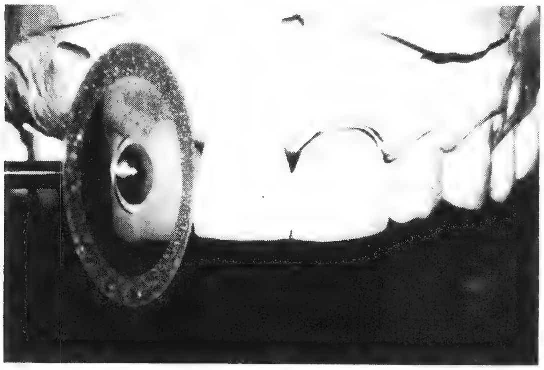


FIGURE 23–17 Forming facial embrasures with a thin diamond disc.

too deep, it must be filled in with additional porcelain, and the restoration must be refired.

The occlusion is adjusted, the final shape and surface characterization is developed, and the restoration is cleaned in preparation for surface staining. Stain is placed into the depth of each separation cut to enhance the illusion of individuality of each tooth and over other required areas (see Chapter 25). The prosthesis is glazed, while the surface stains are simultaneously fused in position, and the metal is polished (Fig. 23–18). The usual clinical adjustment and cementation procedures are performed.

Posterior full porcelain coverage restorations require ridge and groove refinement and occlusal adjustment prior to glazing. Also, stains should be applied in the grooves and fossae to create a natural appearance (Fig. 23–19).

POSTCERAMIC SOLDERING

Clinical and Laboratory Considerations

While this discussion focuses on the assembly of type IV alloy partial-coverage retainers with metal-ceramic components (Fig. 23–20), the same principles are used to postceramically assemble a prosthesis that is entirely metal-ceramic.

Prior to postceramic assembly, all metal-ceramic portions of a prosthesis are seated clinically so any required shape and color adjustments can be completed and the porcelain can be glazed. Extensive changes in the basic porcelain color should be anticipated and accomplished internally through color modifiers and internal staining. Large amounts of surface stain should be avoided if the prosthesis is to be assembled postceramically, since experience has shown that thick layers rarely withstand the soldering process without some deleterious change such as bubbling, slight loss of gloss, or discoloration. When a noticeable surface change occurs during soldering, the prosthesis has to be disassembled to allow grinding and reglazing of the porcelain, since the melting range of postceramic solders does not permit the porcelain part of an assembled prosthesis to be reglazed without melting of the solder.

The plaster soldering index may be obtained intraorally or from the working cast in the usual manner (Fig. 23–21A). The parts of the prosthesis are repositioned in the index and attached by small amounts of hot sticky wax (Fig. 23–21B). Excessive use of sticky wax should be avoided, since this makes elimination of the wax residue from the soldering investment assembly more difficult.

The porcelain must be completely covered with about 1 mm of wax so that there is no contact of the soldering investment with the porcelain (Fig. 23–21C,D). If investment is allowed to contact porcelain, this causes fusion of the two, since the porcelain is softened by the heat of the soldering process. Investment particles adhere to the porcelain, leaving a pitted poorly glazed surface, which ruins the natural appearance of the restoration.

Beeswax is recommended for covering the porcelain, since it is not pigmented and can be readily eliminated without leaving a residue on the porcelain surface. Beeswax projections are formed in the usual manner at the facial and lingual aspects of the joint area to create sluiceways in the soldering investment.

Separating medium is then applied to all exposed plaster surfaces, the assembly is boxed (Fig. 23–22A), and conventional gypsum-bonded soldering investment is placed into and around the parts. The use of phosphate-bonded investment is *not* recommended for postceramic soldering, since its use has been associated with the loss of surface glaze.

When the investment is set, the index is removed

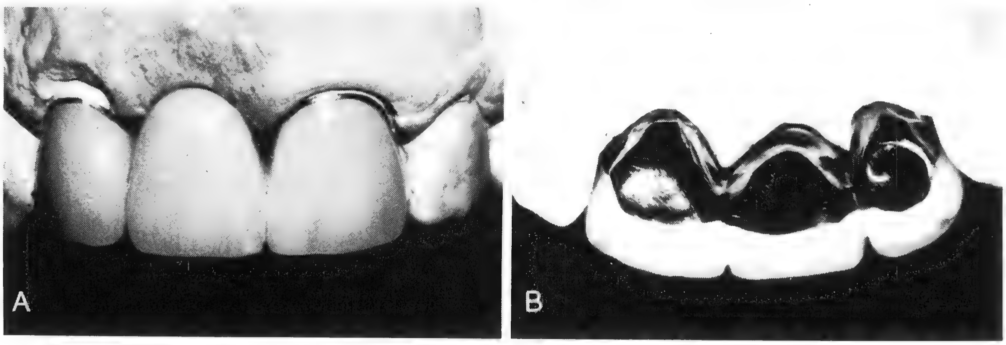


FIGURE 23–18
A,B, Porcelain glazed and alloy polished.

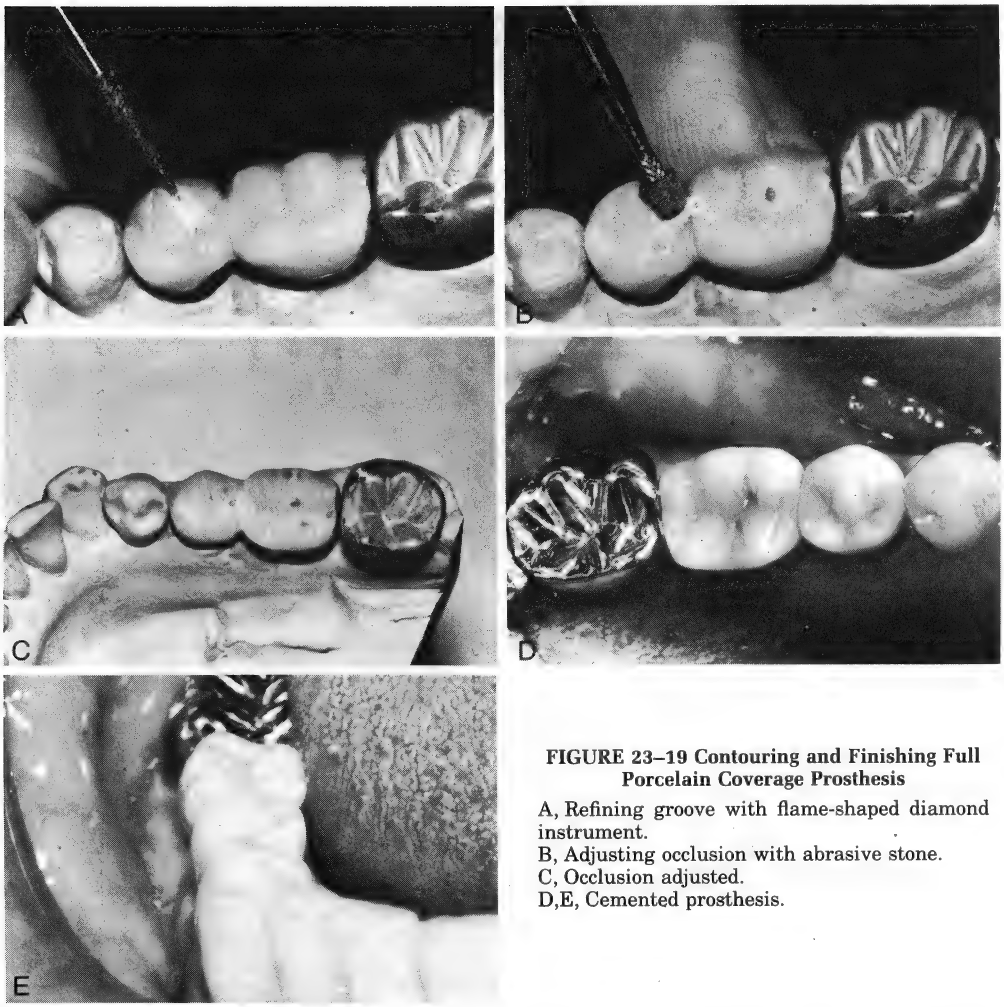


FIGURE 23–19 Contouring and Finishing Full Porcelain Coverage Prosthesis

A, Refining groove with flame-shaped diamond instrument.
B, Adjusting occlusion with abrasive stone.
C, Occlusion adjusted.
D,E, Cemented prosthesis.

(Fig. 23–22B). All wax must be completely removed prior to the soldering process. A residue of wax remaining on the porcelain surface increases the chance of discoloration during the soldering process. A sharp instrument, such as the number 4 PKT carver, is used to remove the sticky wax and the beeswax as much as possible. The remaining wax is eliminated by flushing the assembly with boiling water or by boiling it in chloroform (Fig. 23–22C,D). The chloroform should not be overheated and must be used only in a well-ventilated fume hood.

The proximal surfaces of the castings are coated with

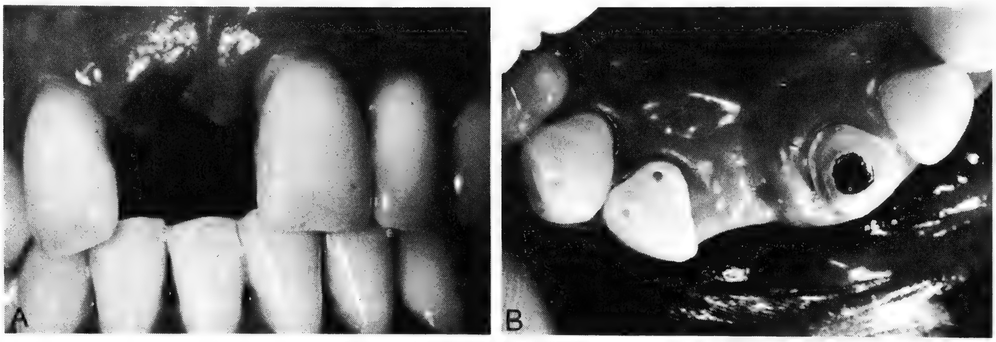


FIGURE 23–20

A, Facial view prior to preparation of central and lateral incisors.
B, Mirror view of metal-ceramic preparation on central incisor and pinledge preparation on lateral incisor.

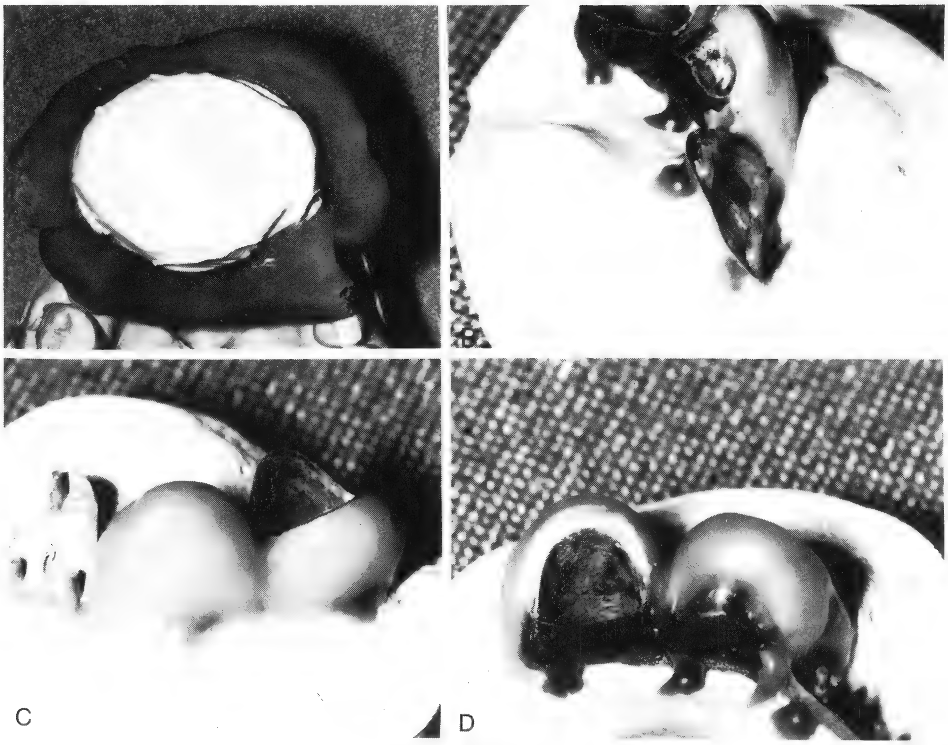


FIGURE 23–21
A, Plaster index made on working cast.
B, Parts assembled in index.
C,D, All porcelain surfaces covered with layer of beeswax.

a thin layer of flux. The quantity of flux must be kept to a minimum, since excess flux can contribute to discoloration of the porcelain, loss of glaze, or both. A barely visible film of flux adequately promotes solder flow. Less porcelain discoloration has been observed when special fluxes designed for postceramic soldering are employed than with petroleum-jelly–based fluxes commonly used for conventional soldering procedures.

The fluxed assembly is heated to the point at which the solder flows. This can be accomplished by applying a gas-air torch or by heating the assembly in a porcelain furnace.

Solder Selection

The solder used in postceramic connection of a prosthesis should have a melting range as far below the porcelain fusion temperature as possible and still possess adequate tarnish and corrosion resistance. Gold solder of 0.585 fineness flows at 783° C (1440° F) and is recommended for this procedure. Solders of lower fineness may not have adequate resistance to tarnish and corrosion. Gold solders with higher fineness (such as 0.650) are acceptable, but their higher fusion temperature produces more heating and softening of the porcelain surface and a greater potential for problems.

Oven Soldering of Gold Alloys

This process is accomplished by preheating to a given temperature, applying solder, and then further heating to the temperature at which the solder flows. An oven that permits viewing of the muffle interior is extremely helpful in order to visually verify proper solder flow and yet not allow the solder to stay molten for a prolonged time which would increase solder joint porosity.

The preheating cycle is started by placing the soldering assembly on a flat firing tray and setting the tray in front of the open muffle of a furnace. The assembly is allowed to warm up for 10 minutes and is placed into the muffle for another 10 minutes to assure uniform heating of the investment. When conventional type IV casting gold alloys are part of the invested prosthesis, oven preheating should be kept below 538° C (1000° F), since excessive oxidation of the type IV alloy occurs above this temperature. Preheating at 427° C (800° F) is commonly used with type IV alloys. If only metal-ceramic units are involved in the soldering operation, the assembly can be preheated to 704° C (1300° F) without producing an oxidation problem.

The preheated assembly is removed from the muffle, and an appropriately sized piece of solder that is coated with a thin layer of flux is placed in the joint area so that it physically contacts both castings (Fig. 23–23A). The assembly is returned to the muffle and placed so that the solder and joint area are readily visible through the window in the muffle (Fig. 23–23B). Although it is not mandatory, a vacuum helps to control alloy oxidation in the muffle and promotes solder flow. Its use is particularly important when a type IV gold alloy is part of the assembly, since this alloy oxidizes more readily than some metal-ceramic alloys. The vacuum is applied after

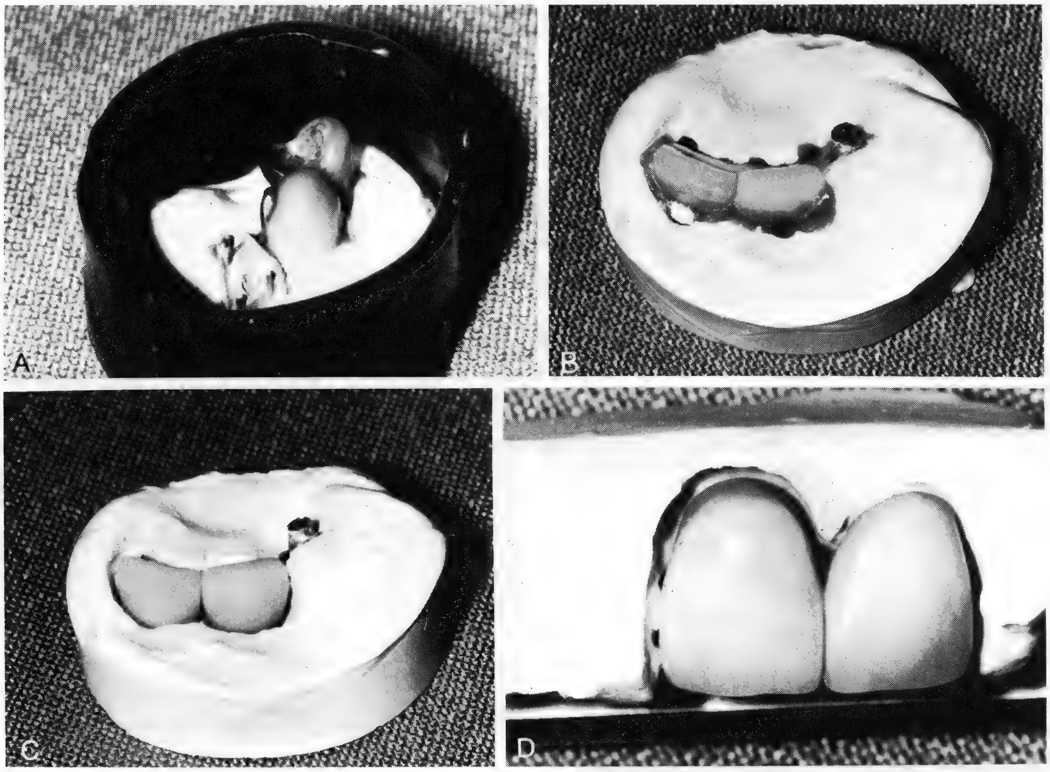


FIGURE 23–22 Soldering Assembly

A, Index and units boxed.
B, Soldering investment assembly after separation of index.
C, Assembly after boiling in chloroform to remove wax.
D, Investment partially broken away after soldering to show the space created between the porcelain and the investment by wax that originally covered the porcelain.

the solder has been placed in the joint area, and the assembly is returned to the muffle.

The furnace pyrometer is set for 55° C (100° F) above the fusion temperature of the solder. The assembly is viewed until the solder flows and good joint form is achieved. Since the entire investment assembly must be raised to the desired temperature, the actual temperature of the castings lags behind the pyrometer reading. Consequently, the furnace may have to idle at the desired temperature for 1 minute or more before the solder flows.

The vacuum is released as soon as proper solder flow is achieved (Fig. 23–23C), and the assembly is removed from the furnace. The prosthesis is allowed to bench cool under a protective cover until it reaches room temperature. It is never quenched.

The restoration is devested, its fit is verified (Fig. 23–23D), and the usual polishing procedures are completed (Fig. 23–23E).

Torch Soldering of Gold Alloys

When a torch is employed, the flame is used to heat the investment, which in turn heats the castings. Prolonged direct contact of the flame with porcelain can cause discoloration, porcelain cracking, or both. The assembly should be preheated slowly and carefully with the torch to prevent rapid thermal changes, which can crack the porcelain. It is possible to use an oven for preheating to the desired temperature and to remove the assembly and complete the soldering process with a torch.

The preheated assembly is placed on a tripod stand, and a Bunsen burner is used to provide heat from below and a torch to heat the investment from above. When the castings exhibit the desired radiant glow, a piece of solder is placed into the joint area and the heating is continued until proper solder flow and joint form are achieved.

Postceramic Soldering of Base Metal Alloys

Base metal castings can be united with conventional gold solder after the application of porcelain. When good solder flow is achieved, the resulting joint strength appears to be quite adequate. The difficult aspect of the process is controlling the base metal oxide that forms rapidly and impedes solder flow. Large amounts of flux are required to help control oxidation, and this makes

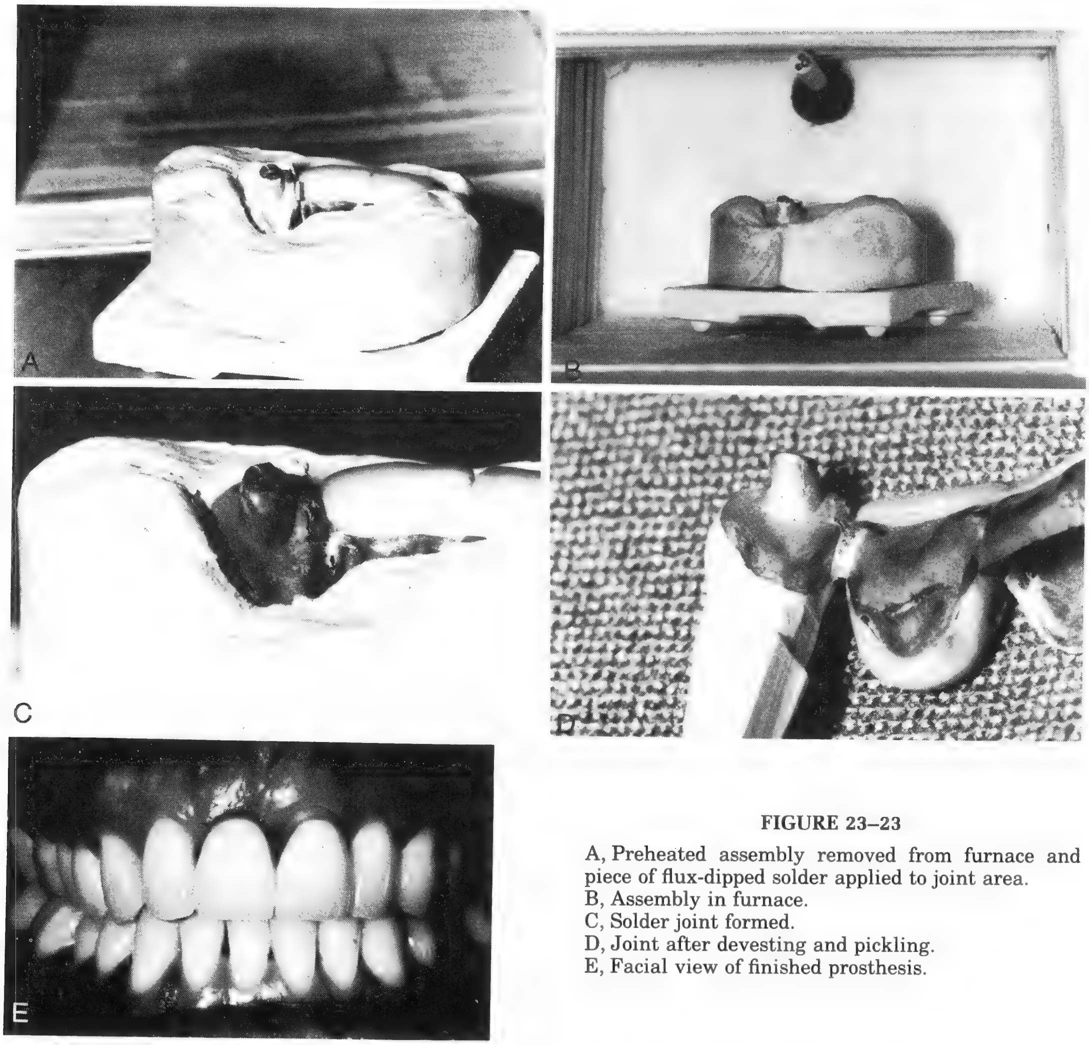


FIGURE 23–23

A, Preheated assembly removed from furnace and piece of flux-dipped solder applied to joint area.
B, Assembly in furnace.
C, Solder joint formed.
D, Joint after devesting and pickling.
E, Facial view of finished prosthesis.

it difficult to avoid porcelain discoloration and surface deterioration. If a torch is used, the reducing zone of the flame must be kept in the immediate vicinity of the joint. Any removal of the flame from a heated base metal allows the formation of sufficient oxide to impede subsequent solder flow. Maintaining the flame in close proximity to the joint area and surrounding porcelain also increases the potential for porcelain cracking and discoloration. Oven soldering in a vacuum to help control oxidation may be the best solution to the difficult problem of postceramic soldering of base metal alloys.

PROSTHESIS DISASSEMBLY

Should the restoration not fit properly and disassembly be required, the usual process of holding the prosthesis over a Bunsen burner to melt the solder is not advisable, since this frequently results in cracking of the porcelain. A safer technique is to cut the joint with a thin diamond disc (0.2 mm thick) until the joint size is small enough that the remainder fractures under manual pressure. Cutting entirely through the joint often creates an excessive gap between the parts. If this cutting process is not possible owing to difficult access, the prosthesis can be furnace-heated with the retainer adjacent to the defective joint left unsupported by the firing tray and thus hanging in space. When the fusion temperature of the solder is reached, the retainer often falls free from the remainder of the prosthesis. Another method is to rapidly remove the prosthesis from the oven when the desired temperature is reached and to grasp the retainer with cotton pliers or needle holders to produce separation, since the solder tears at a temperature slightly below its fusion temperature.

PROBLEMS IN POSTCERAMIC SOLDERING

The problems encountered when all-metal restorations are soldered, such as incomplete connectors and failure of the prosthesis to fit, can also be encountered with postceramic soldering. Other problems are related to the presence of porcelain and involve loss of glaze

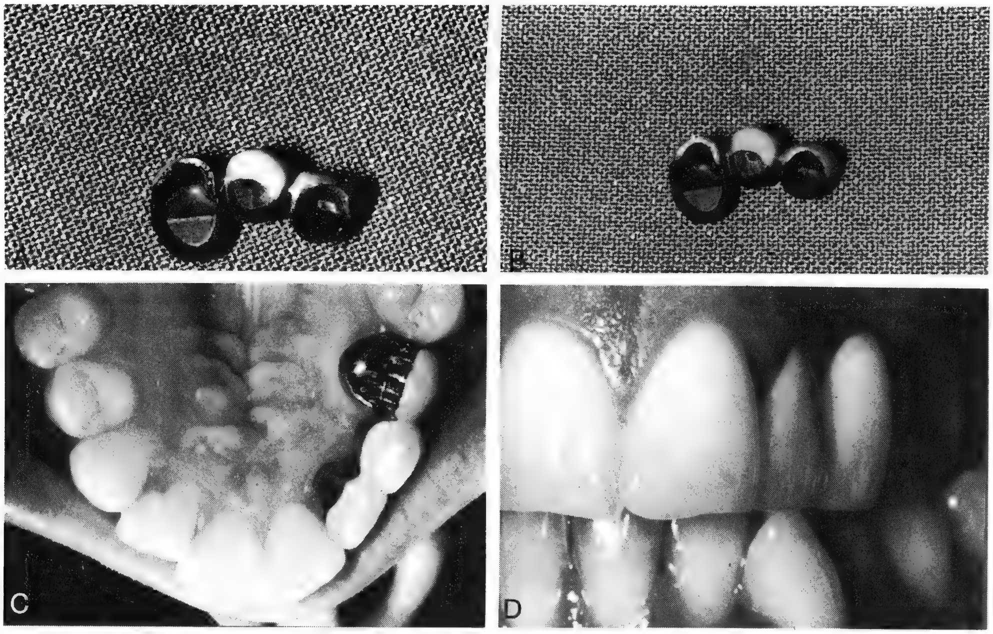


FIGURE 23–24 Collarless Metal-Ceramic Prosthesis

A, Porcelain contoured with platinum foil still attached.
B, Porcelain glazed and foil removed.
C,D, Cemented prosthesis.

and surface roughness, discoloration, cracking of the porcelain, or a combination of these.

Very rapid heating or cooling can cause the porcelain to crack. This problem is less common with oven soldering because of more uniform heating but still can occur if the hot prosthesis is cooled too rapidly. During torch soldering, direct contact of the flame with unheated porcelain often causes cracks to form.

Porcelain discoloration can occur when excessive flux is used or if wax is present on the porcelain (particularly sticky wax or highly pigmented waxes). A muffle that has been contaminated by alloy or solder constituents from previous oven heating procedures can also cause discoloration, as can direct contact of the flame with porcelain near the solder joint.

Localized surface roughness is most often caused by investment contacting the porcelain surface. The refractory particles become fused in place during the soldering operation. Loss of glaze is more frequent when a phosphate-bonded investment is used to hold the parts during soldering. Excessive flux can also have a deleterious effect on the glaze. Thick layers of overglaze or stain appear to be more susceptible to surface attack and glaze deterioration during postceramic soldering.

COLLARLESS METAL-CERAMIC FIXED PARTIAL DENTURES

Fixed partial dentures can be fabricated with collarless metal-ceramic abutment retainers (Fig. 23–24), but technical difficulty is likely to be encountered when the marginal areas are refined, particularly interproximally because of restricted access with rotary instruments. When platinum foil is used, the technical difficulty can be reduced by postceramic assembly of the prosthesis because small sections are more accessible than an assembled prosthesis (Fig. 23–23). However, accessibility is still more critical with the platinum foil technique, and therefore when small cervical embrasures are encountered, the direct lift-off technique can be advantageous.

24

Color and Shade Selection

A basic knowledge of color is essential for successful clinical shade selection. E. Bruce Clark, a dentist, described color and its proper usage to the profession in the 1930s.* Unfortunately, 40 years elapsed before a real concern for color in dentistry was again generated.

COLOR AND LIGHT

The color of an object is determined by the light that enters the human eye from that object. The color that is perceived is the result of a light source, the object that absorbs, transmits, reflects, or scatters the light from this source, and the interpretation of the result by the human visual system.

Light is a form of visible energy that is part of the radiant energy spectrum. Radiant energy possesses specific wavelengths, which may be used to identify the type of energy. Wavelengths are measured in nanometers (nm), with 1 nm being a billionth of a meter.

The visible spectrum ranges from 400 to 700 nm. Wavelengths shorter than visible light include ultraviolet, x-rays, gamma, and cosmic rays. Above the visible spectrum there are infrared, microwaves, television, radio, and electrical waves.

When daylight is made to pass through a crystal prism, as was done by Isaac Newton in 1666, it is bent, and each wavelength changes direction by a different amount. This separates the various wavelengths, and the individual colors of the visible spectrum are seen (Plate 24–1A). Passing these individual colors through other prisms produces no further change. Thus, it can be demonstrated that daylight is composed of all the colors of the visible spectrum and that "white" light is produced when all these colors are combined.

COLOR MIXING

Three large bands of color (red, green, and blue) are observed in the visible light spectrum (Plate 24–1B). These are the primary, or basic, colors of the spectrum. They can be combined to make all the other spectral colors but cannot be produced by mixing of other colored

*Clark EB: Tooth color selection. J Am Dent Assoc. 1065, 1933.

PLATE 24–1

See figures on the opposite page

A Individual colors of visible spectrum separated by passing light through a prism.

B Light-mixture or additive color mixing system.

C Pigment-mixture or subtractive color mixing system.

D The color wheel.

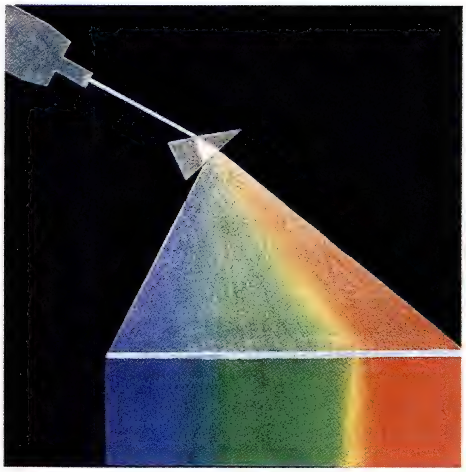
E Munsell student chart showing Hue, Value, and Chroma. (Courtesy of the Munsell Corporation, Baltimore, MD.)

F Munsell Hue, Value, and Chroma scales in color space. (Courtesy of the Munsell Corporation, Baltimore, MD.)

G Munsell color solid. (Courtesy of the Munsell Corporation, Baltimore, MD.)

H Cross section through Munsell color solid. (Courtesy of the Munsell Corporation, Baltimore, MD.)

PLATE 24–1



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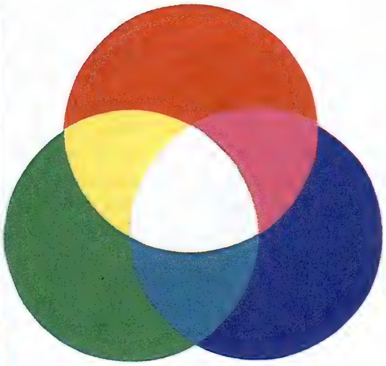

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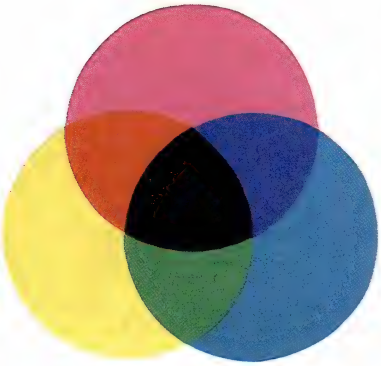

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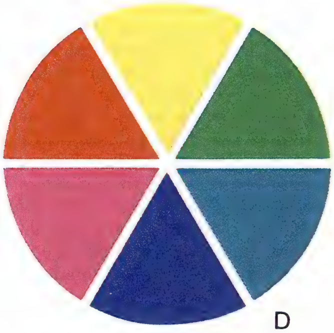

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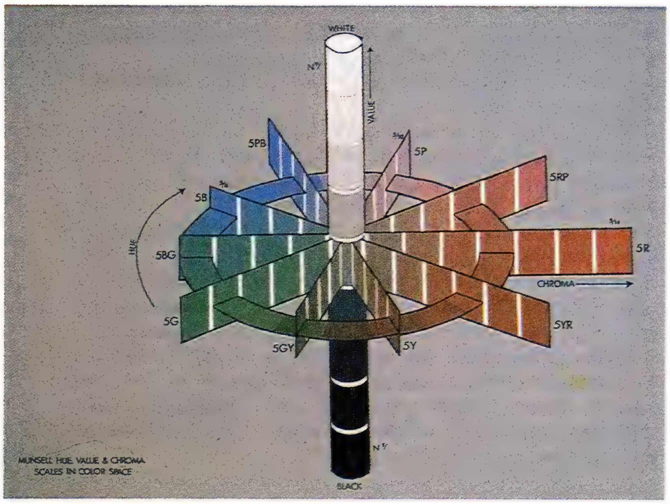

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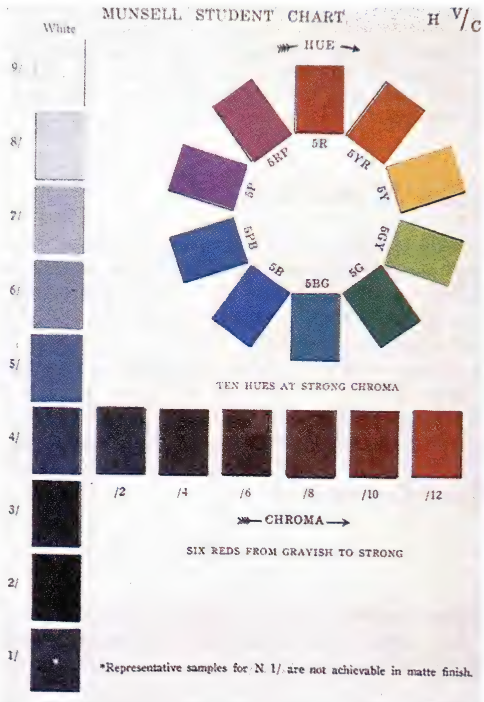

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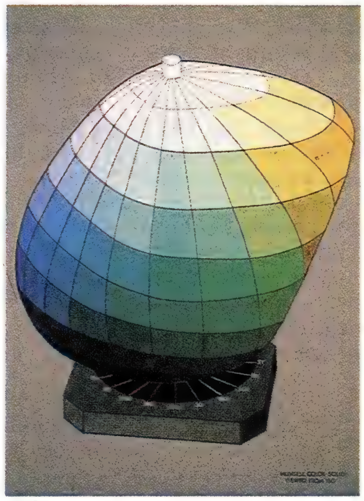

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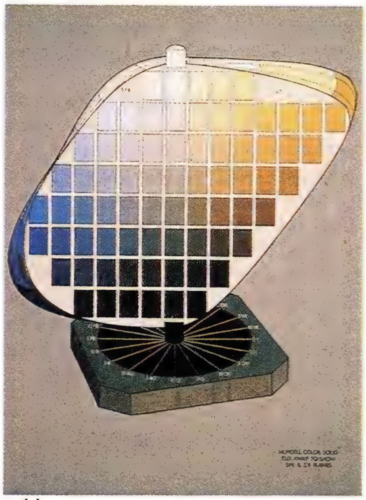


H

lights. These are termed the *light-mixture primary colors*.

Mixing of two of the light-mixture primary colors produces a *secondary color*. For example, mixing red and green produces yellow. The other secondary colors are cyan, which is formed by combining green and blue, and magenta, which is produced by mixing red and blue.

This type of mixing has been termed the *light-mixture*, or *additive, color mixing* system and applies only to combining lights or illuminants.

Another related color network used in fields such as painting and printing is the *pigment-mixture system*, which is also called the *subtractive color mixing* system. The secondary colors in the additive color mixing system are the primary colors in the subtractive color system. Thus, the primary colors in the subtractive, or pigment-mixture, color system are yellow, cyan, and magenta and these form the basis for the derivation of the other colors in the pigment-mixture system (Plate 24–1C). Mixing of two of the subtractive primary colors results in the formation of a secondary color. For example, green is produced by mixing cyan and yellow.

In dental ceramics, both additive and subtractive color concepts are used.

It has been incorrectly stated in some publications regarding color that yellow, blue, and red are the three primary colors of the subtractive, or pigment-mixture, color system. The discrepancy between this and the previously named primary colors is related to differences in terminology and to the name applied to a particular color by the different people who work in the field of color theory (theoreticians, scientists, photographers, television and film technicians, printers, reproduction workers, designers, painters, and decorators). Efforts are being made to standardize terminology in order to ensure accuracy with regard to color language, with magenta, cyan, and yellow being the correct names for the subtractive primary colors.

Color Wheel

The primary and secondary colors have been arranged in the form of a wheel in which the individual colors form parts of the rim of the wheel (Plate 24–1D). This arrangement has been called the *color wheel* or *color circle*. It is produced by bending the spectrum of light into a circle.

Colors directly opposite each other on the color wheel are termed *complementary colors*. A straight line that is drawn from a particular color through the center of the circle also passes through the complementary color on the other side of the circle. For example, the secondary color blue is opposite the primary color yellow and is thus the complementary color of yellow in the subtractive color system. The result of mixing a color with its complementary color is achromatic (colorless). When mixed, any two complementary colors produce an achromatic result. Mixing of the three primary colors also produces an achromatic result.

DESCRIBING COLOR

While the color wheel provides a basis for understanding the mixing of colors, it does not allow an accurate description of color. Royal B. Farnum stated that to the average man and woman color has remained something of a mystery, an expression of Nature that is taken for granted but not fully understood.

The form of an object can be precisely determined by measuring its three dimensions. Color also has three dimensions, and without the use of these measurements, it is not possible to adequately describe color. An example of the frustration that can result from describing color without using its three dimensions was written by Robert Louis Stevenson in 1892. This was quoted by A. H. Munsell in his book describing the three dimensions of color.* The wording is reminiscent of the color description of teeth that often accompanies a work authorization form sent to a dental laboratory for the fabrication of a porcelain restoration.

Writing from Samoa, Stevenson sent the following letter to a friend in London:

> Perhaps in the same way it might amuse you to send us any pattern of wallpaper that might strike you as cheap, pretty and suitable for a room in a hot and extremely bright climate. It should be borne in mind that our climate can be extremely dark too. Our sitting room is to be a varnished wood. The room I have particularly in mind is a sort of bed and sitting room, pretty large, lit on three sides and the color in favor of its proprietor at present is a topazy yellow. But then with what color to relieve it? For a little work room of my own at the back, I should rather like to see some patterns—well, I'll be hanged if I can describe this red—it's not Turkish and it's not Roman and it's not Indian, but it seems to partake of the two last, and yet it can't be either of them because it ought to be able to go with vermillion. Ah, what a tangled web we weave—anyway, with what brains you have left choose me and send me some—many—patterns of this exact shade.

Munsell commented on this letter of Stevenson's by saying:

> Thus one of the clearest and most forceful writers of English finds himself unable to describe the color he wants. And why? Simply because popular language does not clearly state a single one of the three qualities united in every color, and what must be known before one may even hope to convey his color conceptions to another.

MUNSELL COLOR ORDER SYSTEM

Munsell, while teaching color composition and artistic anatomy, felt a need to describe the colors of his sketches in definite terms to his students. This led to the development of the *Munsell Color System*, which is presently a widely used visual color order system.

The three dimensions were defined as *hue, value*, and *chroma*. It is possible to vary each of these qualities without disturbing the other. The ability to understand each of these dimensions and separate them from one another is fundamental to an understanding of color as it relates to dental ceramics.

Hue

Munsell described hue as "that quality by which we distinguish one color family from another, as red from yellow, or green from blue or purple." It is the family

*Munsell AH: A color notation. Baltimore, MD, Munsell Color Co., 1975.

name we apply to a group of colors. There are ten hue families in the Munsell Color Order System, and they are designated by the following upper-case letters: R for red, YR for yellow-red, Y for yellow, GY for green-yellow, G for green, BG for blue-green, B for blue, PB for purple-blue, P for purple, and RP for red-purple (Plate 24–1E). Each of these ten hues is further subdivided into ten numbered segments. The middle red would thus be 5R.

VALUE

In describing value, Munsell stated that "it is that quality by which we distinguish a light color from a dark one." This is an achromatic or colorless distinction. The possible range of values used in describing the lightness or darkness of a surface in the Munsell Color System extends from zero to ten. Black is zero and white is ten with a range of grays between these end points of the scale (Plate 24–1E). The value of a color is determined by which one of the grays it matches on the scale. Colors with low value numbers are termed dark colors, and one with high value numbers are called light colors. A black-and-white television tube emits only a range of values.

In order to compare the color match between a restoration and tooth, value is generally considered to be the most important of the three dimensions of color. One reason is that value differences are readily detected by individuals untrained in color perception, and restorations with improper value are frequently described by patients as being too dark or too white (Fig. 24–1). Another consideration is that value differences are more easily detected at a variety of viewing distances (both close-up and at a distance), whereas differences in hue and chroma become more difficult to quantify as the viewing distance increases.

CHROMA

Munsell described chroma in the following manner: "It is that quality of color by which we distinguish a strong color from a weak one; the degree of departure of a color sensation from that of white or gray; the intensity of a distinctive hue; color intensity."

The chroma scale starts from zero, or achromatic, with increasing numeric values indicating stronger colors. In terms of chroma, color is defined by Munsell as weak, moderate, and strong. A strong chroma would be in the range of seven to ten. There are standards for very strong chromas above ten.

Different chromas of a particular color are arranged from those of least purity or intensity on the left to those of greatest purity on the right. Plate 24–1E shows six reds arranged in ascending order from a weak one (grayish) on the left to a strong one on the right.

Figure 24–1 Prosthesis exhibiting too high a value.

RELATIONSHIPS BETWEEN THE DIMENSIONS OF COLOR

The significance of the three dimensions of color is not fully realized until they are related to each other three-dimensionally as was done by Munsell when he formulated his Color Order System.

The Munsell color solid can be represented in the following manner. The hues are uniformly spaced around the central axis of the color wheel. The center of the wheel or axle is the achromatic or value portion. Each spoke of the wheel represents the gradations in chroma occurring within a hue. Plate 24–1F demonstrates one wheel with the hues designated around the periphery of the wheel, the center value axle, and the spokes representing increased chroma going from the center of the wheel toward the rim. The three-dimensional color solid is not complete unless there are wheels representing each value level stacked on top of each other (Plate 24–1G). The wheels on the top of the stack have a higher value than those on the bottom of the stack. The wheels are not the same size because it is not possible to achieve the same degree of color purity, or chroma, for all hues. Sectioning of the solid vertically allows the relationships between hue, value, and chroma (Plate 24–1H) to be viewed and aids in an understanding of the three dimensions of color.

The designation of a particular color located in the Munsell solid is provided by the notation H V/C, where H stands for hue, V for value, and C for chroma. The notation 5R 4/6 would mean the hue is medium red, the value level is four, and the chroma is six. A color differing only in value and being lighter would be directly above the previous sample.

COLOR OF HUMAN TEETH

Clark was the first to accurately describe the color of teeth. In 1931, he reported his color data from a visual analysis of 6000 teeth from 1000 of his patients over an 8-year period.* He found a hue range from 6 YR to 9.3 Y. This range can be exactly located on the Munsell color wheel by using the ten subdivisions of each hue on the wheel. He found the value range to be 4/ to 8/ and the chroma range from /0 to /7.

Other studies involved color measurements made by a spectrophotometer. Sproull established a hue range of 7.5 YR to 2.7 Y, a value range of 5.8/ to 8.5/, and a chroma range of /1.5 to /5.6.† Lemire and Burk's hue range was from 8.9 YR to 3.3 Y, the value range from 5.81/ to 7.98/, and the chroma range from /0.8 to /3.4.‡

*Clark EB: An analysis of tooth color. J Am Dent Assoc 18:2093, 1931.

†Sproull RC: Color matching in dentistry. Part II. Practical application of the organization of color. J Prosthet Dent 29:556, 1973.

‡Lemire PA, Burk B: Hartford, CT, J. M. Ney Co., 1975.

In summary, the hue range of teeth lies in the yellow-red to red portion of the color wheel. The value range of teeth is toward the lighter portion of the scale, which indicates that very dark teeth were not found in these studies. The chroma range is toward the lower portion of the chroma scale, which indicates that strong colors were not found among the studied teeth.

DENTAL SHADE GUIDES

Shade guides are examples of the various color combinations available from manufacturers of denture teeth, restorative resins, and porcelain. These samples are compared with the natural teeth, and the closest color match is determined.

While the principles of using these different shade guides are the same, a distinction must be made between the guides designed for use with ceramic restorations and those designed for other purposes.

Shade guides used for color matching of a ceramic restoration to a natural tooth should be limited to those for which porcelain powders are specifically manufactured to match the color combinations in the shade guide. Figure 24–2 shows two representative shade guides.

Selecting the color from a shade guide for which there are no manufactured porcelain powders involves transposing that color selection into one from another shade guide that has porcelain powders designed for it. This transposition is a matter of visual interpretation, and different opinions are frequently expressed as to which shade specimen from one guide more nearly matches a given specimen from another shade system.

Another distinction to be made in selecting the color for a restoration is to use a shade guide that has porcelain powders available for the specific type of ceramic restoration to be made. Certain shade guides have only porcelain powders for fabricating metal-ceramic restorations. Use of such a guide in selecting the color for a porcelain jacket crown would lead to difficulty owing to the need for transposition into another shade system.

Although no single shade guide or combination of guides includes all of the color combinations that may be encountered in clinical practice, a reasonably high level of clinical color matching has been achieved, which attests to the artistic skills of many dentists in selecting the best available shade and determining what color modifications are necessary to further enhance the color match.

Figure 24–3 Comparing a shade guide specimen with natural teeth.

GUIDELINES FOR CLINICAL SHADE SELECTION

Clinical shade selection involves direct visual comparison of the different color samples that are present in a shade guide with the natural teeth and determination of which one best matches the teeth (Fig. 24–3).

There are several guidelines that are helpful in the development of clinical color matching skills.

LIGHTING

Light comes from a variety of sources. It occurs naturally as sunlight, and artificially it is produced by a flame, by electric incandescent bulbs, and by fluorescent, mercury, and sodium lamps.

Sunlight is the traditional source of light for performing work involving color. Northern-exposure sunlight in the middle portion of a day that is slightly overcast is considered to be the optimal source. This is known as *standard daylight.* Light of this nature is not always present during color matching procedures, since the time of day and time of year affect the color of sunlight. This fact, coupled with the necessity to perform color procedures in the absence of daylight, has brought about the need for artificial lighting systems that simulate sunlight.

The suitability of artificial lighting for use in color comparison procedures is based on the ability of the light source to approximate standard daylight. The reproducing capacity is measured by using such references as the color temperature, spectral reflectance curves, and a color rendering index (CRI).

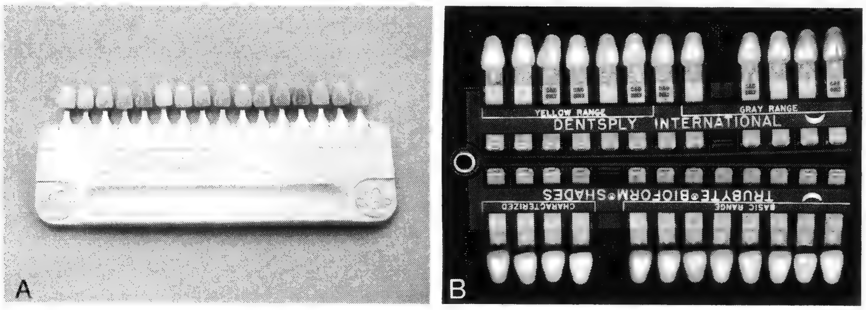


Figure 24–2

A, Vita* Lumin-Vacuum shade guide.

B, Dentsply† Bioform shade guide.

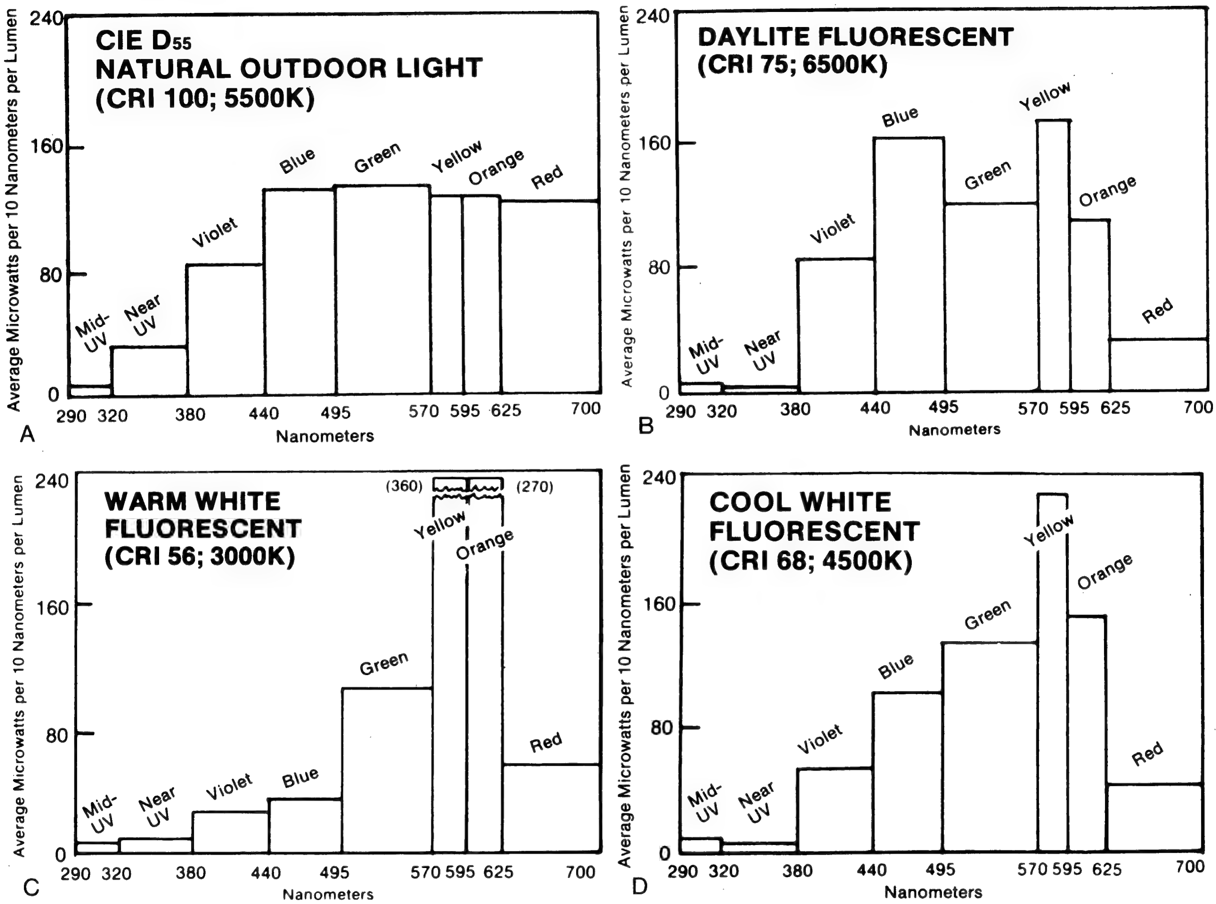
*Vident, Baldwin Park, CA 91706.

†Dentsply International, York, PA. 17404

The color temperature of a particular light source is determined by relating the color of the light to that produced by a standard blackbody when heated to a known Kelvin temperature. The blackbody progresses through a variety of colors when it is heated (from red at 1000° K to white at 5000° K to a pale blue at 8000° K). Sometimes the terms "red hot" and "white hot" are used. The Kelvin temperature is calculated by adding 273 to the Celsius temperature of the heated blackbody. The color temperature of some commonly encountered light sources are: a candle—2000° K; a 200-watt incandescent lamp—2900° K; a warm white fluorescent bulb—3000° K; a cool white fluorescent bulb—4200° K; and the light from an overcast sky—around 6500° K.

Spectral reflectance curves show the relative amounts of light of each wavelength produced by a light source. Figure 24–4 graphically portrays the amount of different wavelengths present in light from the different types of lighting sources.

A chromaticity diagram plots a light source on the



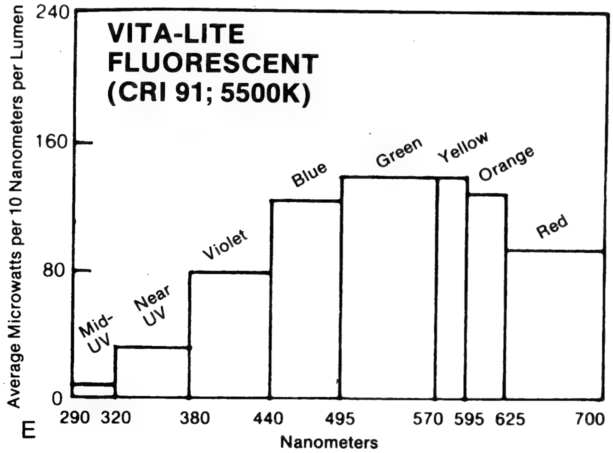


Figure 24–4 Relative amounts of light of each wavelength produced by different light sources. (Courtesy of The Duro-Test Corporation, North Bergen, NJ.)

basis of the relative amounts of the three light primaries (red, green, and blue) that it takes to match the color. There is only one point on the diagram at which there is equal energy from all the hues in the spectrum. This "white light" is given a *color rendering index (CRI)* of 100, which is the best source for color comparison procedures. Artificial lights are not available with a color rendering index of 100, but those with an index over 90 are considered adequate for color matching. Some commonly used light sources have the following color rendering indices: daylight fluorescent—75; warm white fluorescent—56; cool white fluorescent—68.

From the previous discussion, it is apparent that most of the commonly used artificial light sources are not completely adequate for color matching procedures. However, there are several color corrected fluorescent lamps with color rendering indices over 90 that do provide an environment conducive to optimal color matching in the dental operatory (Verd-A-Ray's Indoor Sun and CritiColor, Duro-Test's VitaLite, and General Electric's Chroma 50). Although these lights provide the best environment for color matching, the selection should be checked under other commonly used lighting systems because of the problem of metamerism.

Metamerism is the phenomenon occurring when the color of two objects appears to match under one lighting source but not under a different source. Metamerism appears in dentistry as a result of differences in the optical properties of natural tooth structure and dental porcelain related to their chemical and physical differences. In addition, human teeth are often viewed under many different lighting conditions. Consequently, porcelain and tooth structures may appear to match each other under one light source and not under another.

A color choice that looks good under all lighting conditions is highly desirable but not always achievable. A decision may have to be made to accept the best match available for the light source under which the teeth are most commonly viewed. Incandescent lighting and cool white fluorescent lighting are commonly encountered in the home and office, respectively, and should be available in the dental office for comparative purposes.

Color-corrected and other commonly used light sources should also be available in the ceramic laboratory. This helps to verify the color match of the restoration with the shade guide specimen during fabrication.

The use of a dental operating light is not recommended because it is often overpowering and therefore interferes with fine discrimination of the three dimensions of color (Fig. 24–5). Use of only ambient lighting provides a more natural lighting environment.

Amount of Lighting

The recommended minimal amount of room lighting for proper color matching in the dental office is about 200 foot-candles when measured at 30 inches above the floor. This level of lighting is approximately the same as that from three ceiling fixtures each containing four 48-inch tubes installed in a 10-foot by 10-foot room.

In addition to improving the color matching environment, this amount of lighting also helps to reduce eye fatigue. When there is a significant difference between the brightness level in the mouth and that of the immediate surroundings, excessive eye fatigue occurs.

Figure 24–5 Brightness of operatory lights interferes with accurate shade selection.

The unit light should be adjusted in such a way that it provides the amount of light necessary for proper execution of intraoral procedures. With this brightness level established, the brightness of the surrounding area should be controlled so that the visual adaptation level does not change significantly when the observer is looking away from the mouth. For minimal transient adaptation, a 3:1 brightness ratio between the intraoral area and surroundings must be maintained. The use of the proper number of fluorescent tubes creates the proper brightness ratio between the ambiently illuminated surroundings and the oral cavity.

Location of Lighting

Five types of illumination systems have been studied for their effectiveness in illuminating a dental operating room. The most nearly ideal illumination was found to be that provided by the all-luminous ceiling, open-perimeter recessed fixtures, and open-perimeter surface mounted fixtures. The all-luminous installation is achieved by having the entire ceiling of the room illuminated by fluorescent lighting. The open-perimeter installation involves using fluorescent fixtures around the entire perimeter of the ceiling (either recessed or surface-mounted) with the center of the ceiling having no fixtures.

The fixtures should be positioned so that light is delivered evenly to the desired location. Recessed ceiling lighting should restrict lateral and upward loss of light by providing a proper reflective surface to project the light downward.

A diffuser is generally used to cover the fluorescent tubes in order to achieve a uniform brightness with no tube images visible. These features contribute to patient comfort when a lighting system is viewed from a supine position. However, the diffuser should pass at least 85 per cent of the light and allow the passage of full-spectrum lighting over both the visible and ultraviolet areas. A good lighting fixture company can help in

obtaining color-stable acrylic resin diffusers that meet these requirements. Routine cleaning is necessary to ensure that there is no alteration of the light as it passes through the diffuser.

Restricting Light

When light rays enter the eye, they strike the retina. The light first penetrates a layer of nerve fibers, then passes through several layers of cells, and finally reaches the rods and cones, which are embedded underneath. The rods and cones of the retina form the chief component of the retinal receptor complex. The rods detect only lightness and darkness, the achromatic aspects of an object (value). The cones perceive the chromatic aspects of an object (hue and chroma).

The rods and cones are not distributed equally over all portions of the retinal layer. The cones predominate toward the center of the retina, that is, in the zone directly behind the lens. There is a small oval area about 3 by 5 mm at the retinal center or posterior pole of the eyeball known as the macula lutea. At its center is a 0.5-mm depression known as the fovea centralis (Fig. 24–6). Nearly all of the cones are in or near the fovea centralis, while the rods predominate in the peripheral areas of the retina.

This fact can be advantageously used to improve the perception of value, which is generally considered to be the most important of the three dimensions of color. Squinting restricts the amount of light entering the eye so that the focus is less acute, which shifts the visual response from the foveal area to peripheral areas of the retina in which the rods predominate. The rods are capable of responding to very low light levels, and squinting thus helps the viewer to determine whether a value difference exists between the shade guide specimen and the tooth.

Conversely, the determination of hue and chroma requires the presence of an adequate amount of light.

Surrounding Colors

When light strikes an object, some wavelengths are absorbed by the object and some are reflected. What is commonly called "the color of an object" is actually the color of the light that has been reflected.

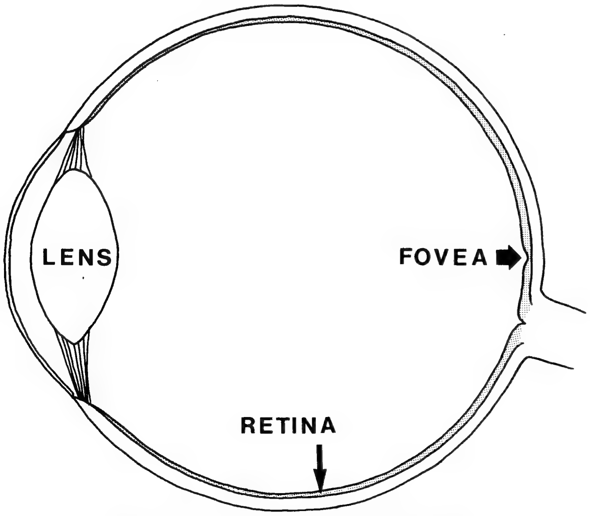


Figure 24–6 Cross section of the eye.

In the dental operating room, light strikes a variety of objects in the surrounding environment and is reflected. Even if there is a good light source present, the light can be altered into an unacceptable form by the time it reaches the mouth in which the actual shade selection is being performed. For example, sunlight can be altered as it passes through the window by the presence of colored curtains. Both sunlight and artificial illumination can be drastically changed by striking brightly colored walls or other areas of high chroma on their way to the patient.

The dentist's or patient's brightly colored clothes can reflect undesirable colors into the selection environment. The patient's drape can be used to mask an undesirable color in the patient's clothing, provided that the drape itself does not introduce an undesirable reflecting color. Lipstick should be removed so that it does not interfere with the perceived color.

It has been recommended that dimmer controls be included in the lighting system for a room in which an unacceptably colored environment is present. A reduction in ambient lighting aids in preventing the reflected light from affecting the shade selection. A portable color-corrected light source can be employed to provide oral lighting. This type of procedure can be effective but requires practice in order to obtain a natural perspective owing to low room lighting and relatively high oral illumination.

A light gray is the ideal background for color matching, according to the American Society for Standard Testing and Materials and the Inter-Society Color Council. The Munsell notation of the correct gray is N7/ to N9/. The N stands for neutral or achromatic and the number indicates the value of the gray. Guidelines have been developed for color schemes in the dental operating room and it has been determined that chromatic surroundings are acceptable as long as the hues present meet certain criteria. High-value pastels are recommended, while the use of large areas of high chroma should be avoided. The portion of the ceiling that is not occupied by the lighting system should be white or off-white with a value of 9 or more. Large vertical surfaces such as the upper portions of walls and high cabinets should have a value of 8 or more and a chroma below 4. Lower wall surfaces and counters should have a value of 7 or more and a chroma below 6. The floors should have a value of 6 or more and a chroma below 3. Another consideration is to avoid surfaces with a high gloss because disturbing glares, which interfere with good visual accuracy, are produced.

Time of Selection

The color selection process should be performed when sufficient time can be devoted to identify the best color match. Too often the process of tooth reduction, impression, and temporary restoration fabrication become the main concern of the dentist, and the shade selection is squeezed in at the end of an appointment.

Good procedure involves selecting the shade at the diagnostic appointment when it is determined that a ceramic restoration is necessary. This should be included as part of the initial clinical record and entered in the

patient's chart for future reference. The shade is confirmed at the time of the preparation appointment to make certain the choice made at the diagnostic appointment is correct.

When the selection is verified at the preparation appointment, this should be done prior to tooth reduction. After the preparation has been completed, the eyes are fatigued as a result of the amount of concentrated focusing required during the procedure.

The retina exhibits adaptation if an object is viewed continuously for time periods greater than 15 seconds, and similar colorants begin to look the same. This phenomenon necessitates glances of short duration to compare the color of a porcelain sample with that of a tooth. Five-second glances with periods of rest instead of prolonged staring are recommended.

However, there is a staring procedure that can be used advantageously in clinical shade selection. Gazing at a color causes the photopigments in the cones that are sensitive to the involved color to be depleted, but at the same time the eye becomes more responsive to the complementary hue. This phenomenon of negative afterimage can be used to sensitize the eyes to the yellow hues of teeth by gazing at a medium blue card (the complementary color of yellow) and then glancing briefly at the tooth and the shade guide specimen.

Patient Position

Clark, in describing his color system and technique for selecting a shade, stated that "it is extremely important that the patient be in an upright position when the shade is selected so that the teeth may be viewed in the surgery under the same conditions under which they will be seen in his business and social life." This early statement regarding patient position remains most appropriate for clinical shade selection.

Since porcelain and tooth structure appear to be different under certain viewing conditions, the shade matching should take place under the viewing conditions commonly encountered by the patient. Having the patient seated upright and at the observer's eye level thus becomes the most beneficial position for clinical shade selection (Fig. 24–7).

Figure 24–7 Patient in normal sitting posture for shade selection.

Tooth Condition

True color characteristics and the appearance of depth and translucency in a natural tooth cannot be correctly perceived unless the tooth is free of plaque and surface stains (Fig. 24–8A). If necessary, the teeth should be polished prior to shade selection to remove plaque and stains (Fig. 24–8B).

Also, the teeth must be kept moist during shade selection. Teeth can undergo dehydration very rapidly, and even slight moisture changes interfere with the color selection process. As a tooth dehydrates, its value increases, and other apparent changes occur (Fig. 24–9). A selection of a shade at this time leads to a discrepancy between the restoration and the natural tooth when rehydration is complete. Shade matching should never be attempted following long periods of tooth isolation, such as occurs during the use of a rubber dam. The natural moisture content of the tooth must be maintained during the selection process.

Dehydration is particularly a problem when there is difficulty in achieving a clinical color match and considerable time is spent comparing several different shade guide specimens and perhaps multiple shade guides. When this situation is encountered, the patient should be allowed to close the mouth between comparisons so the teeth can be moistened by passing the tongue over them. Applying some of the liquid medium from a stain kit to the facial and lingual surfaces of the teeth with a brush helps to eliminate dehydration. This liquid does not evaporate easily and helps to contain the moisture in teeth while the mouth is open and the lips and cheeks are retracted for the selection process.

Comparison Procedures

The following technique is designed to aid in the selection of the best shade guide specimen after the proper color environment has been established. It is only one of many available techniques.

Holding the entire shade guide adjacent to the teeth can cause confusion, and difficulty may be encountered in determining the best specimen from such a large group of samples. For this reason it is best to evaluate prospective color specimens one at a time by holding them next to the tooth being matched.

A helpful procedure at the beginning of the shade selection process involves evaluating the patient's natural teeth to determine their color characteristics (yellow, red, gray, and so forth) by looking at the cervical aspect of the teeth. When the basic color is visually obvious, the properly pigmented shade guide specimens can be set aside for shade comparison while unsatisfactory ones can be eliminated, thereby reducing the number of choices and making the selection process easier.

Each prospective shade guide specimen should be held next to the tooth being matched and aligned so that light reflects off the shade guide specimen in a manner similar to that of the natural tooth (Fig. 24–3).

The color of the cervical portion of the shade guide specimen is then compared with the natural tooth by using a short-duration glance. It is advisable to look away and rest the eyes on a blue card, then glance back again for verification of the color. The incisal half of the

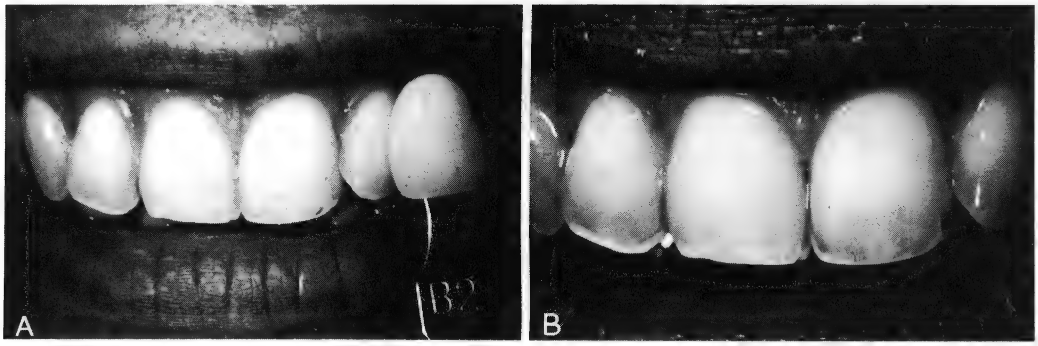


Figure 24–8
A, Dullness of teeth caused by plaque accumulation.
B, Plaque has been removed.

tooth and shade guide specimen can be covered with a finger, and the cervical comparison can be made without distraction from the incisal portion of the teeth. Other samples are observed in the same manner until a decision is made regarding the best cervical color match.

For many teeth, one cervical shade selection is all that is required. However, certain teeth exhibit different zones of dentin coloration, and the shade selection must be performed cervically and repeated for other areas of the tooth, since one dentin color does not provide the multiple color characteristics present in the tooth.

The dentin coloration becomes less intense as the incisal edge is approached, and the tooth becomes more translucent owing to an overall faciolingual thickness being composed of less dentin and thus relatively more enamel. Also, anterior teeth are thinner incisally which allows the passage of more light. The shade selection process should include a determination of where the enamel translucency is visually apparent on the basis of measurements from the incisal edge to the area at which the translucency terminates. These measurements can be transferred to a diagram of the tooth for use during the laboratory fabrication.

It is best to avoid unnecessary involvement of the patient in the shade selection process. For instance, handing the patient all the shade guide specimens can create confusion, since patients are often unfamiliar with the color of their teeth and are not familiar with the color characteristics of the shade guide specimens. Some patients like to be involved in the treatment process, and when this need is sensed, the final selection can be shown to the patient for approval, or the patient can be given the two best possibilities and allowed to participate in the final decision.

Figure 24–9 Dehydrated incisors caused by isolation under a rubber dam.

Selection Distance

Dental procedures are performed in close proximity to the teeth, and there is a tendency to perform the shade selection procedure at the usual working distance (Fig. 24–10A). However, a selection made at 3 to 6 feet from the oral cavity is often more useful, since it is representative of the conditions under which the patient's teeth will most often be observed (Fig. 24–10B). When someone is met for the first time, smiles and greetings are generally exchanged, and it is at this time and distance that ceramic restorations are often detected. If it takes considerable visual study and close scrutiny to determine that a porcelain restoration is present, the color match should be considered very good. This is particularly true when it is the trained eye of a dentist that has difficulty in making the determination.

The distant selection is particularly helpful in evaluating value. Since natural teeth fall into the lower portion of the chroma range, decisions regarding the chromatic aspects of a restoration are more difficult when the observation takes place at some distance, and consequently value becomes more apparent.

Verification

The importance of having the shade selection process performed by a second individual such as a dental assistant cannot be overemphasized. This procedure provides another opinion and helps to compensate for individual eye fatigue and visual color defects.

Verification of the shade should be made on more than one occasion. The shade selection procedure should be initially performed at the diagnostic appointment, as discussed previously. The choice is made by the practitioner without an auxiliary person present. The auxiliary person then makes a selection without the dentist being present, and the two compare their individual choices. This procedure sometimes produces conflicting

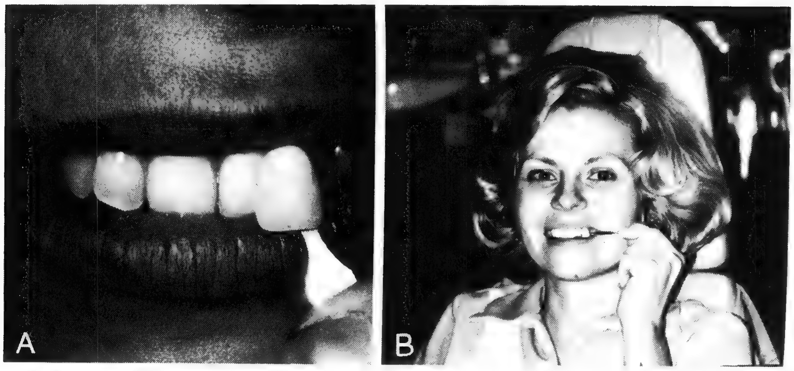


Figure 24–10
A, Close-up shade selection.
B, Selection at 3 to 6 feet.

results, but resolving the discrepancy facilitates determination of the best match from the available choices. The mutual choice is recorded in the patient's record for future reference.

The same procedure is then performed at a subsequent appointment without reference to the patient's record. This serves as a verification of the shade selection by the same people on a different day, perhaps a different time of day, and with a different eye fatigue level. The final shade choice can then be recorded in the patient's record and on the appropriate laboratory work authorization forms.

Diagram

As discussed previously, some restorations require the use of zones of different color in order to achieve a match with the natural teeth. The locations of these zones of color can be measured on the tooth, and the information can be transferred to a diagram. The form and extent of translucency as well as other unique characteristics, such as enamel checks or stained areas, can also be identified and geographically located on a diagram. A simple drawing of the crown form labelled with the appropriate information can be a valuable aid to the dental laboratory technician.

Photograph

While photographs are not accurate representations of clinical color, they can be useful in showing the laboratory technician the extent of translucency and the magnitude and location of surface characteristics.

SUMMARY

From the previous information, it becomes apparent that comparing color samples from a shade guide with natural teeth and arriving at the best selection is a blending of art and science. This process requires knowledge of the dimensions of color as well as clinical experience in an environment that optimizes the selection process.

This skill cannot be thoroughly mastered in the absence of scientific knowledge, nor can it be fully grasped by merely memorizing facts about color. Together, knowledge and experience provide rewarding solutions to this challenging aspect of dentistry.

25

Esthetics in Ceramic Restorations

The term "esthetic" denotes beauty as distinguished from the merely pleasing. Thus, in dentistry, esthetics is that portion of the discipline that deals with retaining or achieving the ultimate in appearance. Several factors are considered essential to creating ceramic restorations that simulate natural tooth beauty and thereby improve a patient's appearance rather than detract from it.

SOFT TISSUE MANAGEMENT

The manner in which the soft tissue is handled can have a profound effect on the natural appearance of a ceramic restoration. Changes in gingival form, color, or position are sometimes observed following cementation but may have been initiated earlier, since many aspects of treatment, if improperly executed, cause esthetically detrimental changes. Also, inadequate general tissue health may produce soft tissue changes even with the most skillful use of acceptable technical procedures. After all, some trauma is inherent in all clinical procedures related to the placement of a ceramic restoration. For this reason, it is imperative that optimal tissue health be established before initiation of any definitive restorative procedure.

Proper oral hygiene must be verified. In its absence, instructions must be given in brushing, flossing, and prosthesis hygiene. Definitive treatment should be delayed until effective oral hygiene can be verified and tissue health optimized. If periodontal treatment is required, it should be completed prior to the beginning of tooth preparation.

FINISH LINE FORMATION

For a variety of reasons, including esthetic requirements, many ceramic restorations must have subgingival margins, and every effort must be made to produce minimal soft tissue trauma as the finish line is formed. Rotary instruments can severely injure or obliterate the gingiva, thus causing soft tissue contours that detract from the esthetic result and that can lead to problems in the maintenance of periodontal health. The interdental papilla is a particularly susceptible structure and is easily traumatized (Fig. 25–1).

FIGURE 25–1 Tissue Damage During Placement of Subgingival Margins

A, Interdental papilla severed during tooth preparation resulted in tissue loss and a dark space between central incisors.

B, Poor gingival form around central incisors several years after tissue was severely traumatized with rotary instruments.

C, Complete loss of interdental tissue between maxillary central and lateral incisors.

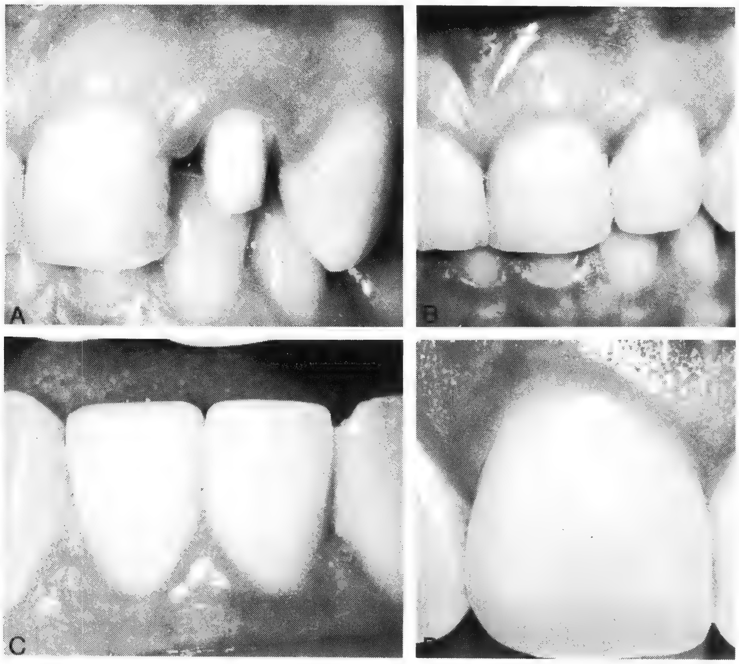


FIGURE 25–2 Acceptable Soft Tissue Reactions to Subgingival Finish Lines

A,B, Lateral incisor with subgingival margin.
C, Mandibular central and lateral incisor metal-ceramic restorations.
D, Central incisor porcelain jacket crown.

Fortunately, there are procedures that can be used effectively to protect the soft tissue from contact with rotary instruments and preserve the natural beauty of the gingiva around ceramic restorations (Fig. 25–2).

Retraction Cord Technique

This procedure involves first reducing the tooth and establishing the preparation form at, or incisally to, the gingiva. In this manner, rotary instruments are kept away from soft tissue contact. Retraction cord is then placed into the sulcus to thereby temporarily displace the gingiva both laterally and apically (Fig. 25–3A). The finish line can be lowered to the level of the retraction cord by using rotary instruments without soft tissue laceration (Fig. 25–3B,C). When the cord is removed and the gingiva returns to its normal location,

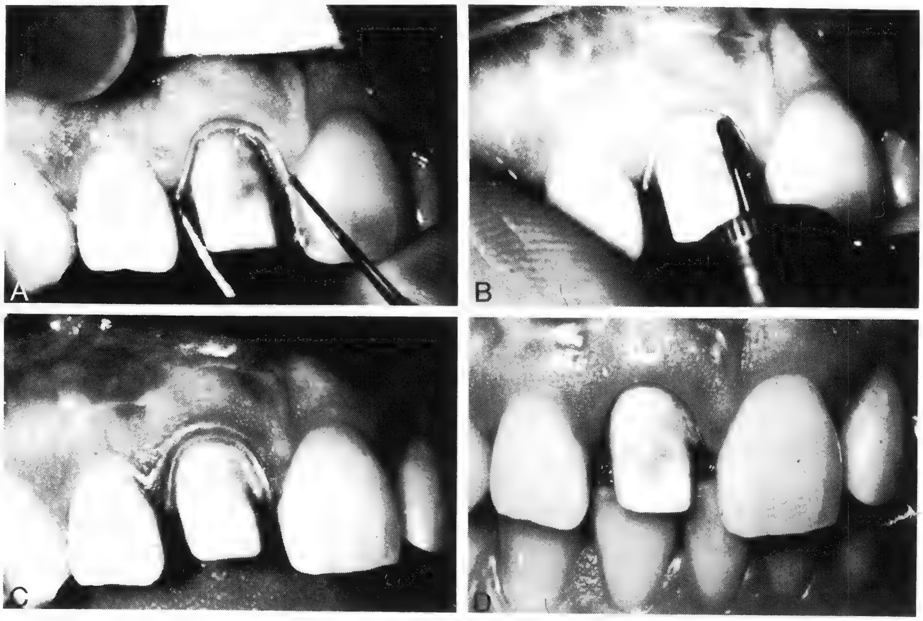


FIGURE 25–3 Forming Subgingival Finish Lines While Using Retraction Cord

A, Cord being placed into sulcus after initial finish line has been located at crest of tissue.
B, Finish line lowered to retracted tissue level.
C, Finished preparation with cord in sulcus.
D, Subgingival finish line with cord removed and tissue returned to normal position.

FIGURE 25–4 Thin interdental papillae preserved by use of retraction cord during shoulder formation.

the finish line is located subgingivally (Figs. 25–3D and 25–4). This order of procedure reduces the soft tissue injury that is often observed when the margin of a tooth preparation is carried directly into the gingival sulcus by using rotary instruments.

Retraction cord could be placed into the sulcus prior to starting the tooth preparation, but this may lead to excessive soft tissue trauma, since extended periods of cord retraction also can be excessively traumatic. Placement of cord after the preparation form has been established minimizes the retraction time. Total retraction time ideally should not exceed 15 to 20 minutes.

If multiple teeth are being prepared with subgingival margins, the following technique can be used. The preparation form is established and the reduction terminated at the crest of the gingiva on all the teeth. Retraction cord is packed around only one tooth, the finish line is positioned farther cervically, and the preparation is completed.

The retraction cord is then removed, the tissue is retracted around the next tooth, and that preparation is completed. This procedure is followed until all the teeth are prepared. The final step is to repack cord around each tooth just prior to obtaining the impression. This technique reduces the trauma associated with prolonged tissue retraction around one tooth during the time that the other preparations are being completed (Fig. 25–5).

FIGURE 25–5 Tissue form and position around multiple preparations with subgingival margins. Note that tissue is not lacerated.

Other factors related to the use of retraction cord are important to minimizing soft tissue trauma. Use of too large a retraction cord or too many cords around a tooth can cause excessive trauma. With healthy gingival tissue, one thin cord is generally satisfactory for anterior teeth and a single medium-sized cord for posterior teeth. Excessive instrument pressure exerted in placing the cord into the sulcus, which occurs more often with excessively large cords, can also produce gingival damage. When the proper cord size is selected and nontraumatic packing pressure is used, the tissue blanching (evidence of reduced blood supply) that is often observed immediately after placement of the cord rapidly disappears. Prolonged blanching is likely to cause detrimental changes in the gingiva.

Hand Instrument Technique

Some operators prefer to use a hand instrument to retract and protect the tissue while a subgingival margin is being formed with rotary instruments.

Impression Procedure

An impression must provide detailed information about the prepared teeth, surrounding intact teeth, and associated soft tissues. To meet these objectives, the gingiva must be recorded in as natural a position as possible so the cast simulates normal gingival relationships. A restoration can then be fabricated that relates harmoniously with the soft tissue and does not promote recession or other adverse reactions by encroaching on the space previously occupied by the gingiva.

Gingival form is recorded best by removing all cord from the sulcus as the impression material is syringed around the prepared teeth. For control of tissue seepage, it can be helpful to leave cord in the sulcus, but this is generally not necessary if the impression material is deposited immediately as the cord is removed. The absence of cord also allows the impression to record more of the unprepared tooth contour that is located cervical to the finish line (Fig. 25–6). The resulting die is more helpful for developing a ceramic restoration that is a continuation of normal tooth contour and that is not overcontoured. An overcontoured restoration promotes plaque accumulation and resultant gingival inflammation.

FIGURE 25–6 Impression of subgingivally prepared mandibular molar. If cord had been left in the sulcus, little if any submarginal tooth contour would have been copied.

FIGURE 25–7 Severe tissue reaction on distal surface of mandibular premolar caused by impression material left in the sulcus.

Following removal of an impression from the mouth, it is important to check the gingival sulcus with an explorer and to remove any remnants of retained impression material. Severe tissue reactions have been observed when impression material has been inadvertently left in the sulcus (Fig. 25–7).

The Temporary Restoration

Temporary restorations serve many functions, as discussed in Chapter 8, one of which is to help prevent esthetically detrimental gingival changes. To accomplish this goal, the soft tissue must be maintained in its normal location and rest against a smooth surface that is readily cleansable. A temporary restoration that is properly contoured and well adapted to the preparation margin and that possesses a very smooth surface promotes the maintenance of tissue position and health. In the case of a temporary fixed partial denture, it is also important to establish cervical embrasures that provide access for oral hygiene aids (Fig. 25–8).

The patient must receive instructions on how to properly clean temporary restorations, and meticulous attention must be given to the described regimen during the period of temporization. The timing of clinical appointments and laboratory fabrication ideally should be arranged so that temporary restorations need not be in position for more than two to three weeks. This reduces the potential for gingival changes, since even the best temporary restoration is inferior to a well-fabricated ceramic restoration.

Many adverse soft tissue reactions observed around final restorations have been initiated by a faulty temporary restoration or a good temporary restoration that has been inadequately cleaned or left in position for an extended time.

Soft Tissue Response to Ceramic Restorations

A poor soft tissue response around a cemented restoration can negate gratifying esthetic accomplishments achieved in the porcelain. The restoration can become visually obvious, whereas in the presence of normal gingiva it would not be readily detected (Fig. 25–9).

Many factors can produce abnormal gingival color or form. As mentioned, this may be the result of some previous aspect of treatment such as laceration of the gingiva with rotary instruments or a poor temporary restoration, and the response only becomes fully manifest following cementation. Also, the patient's gingival health and oral hygiene may be barely adequate, and this, coupled with the normal trauma inherent in placing a restoration with subgingival margins, may alter unfavorably the biologic balance.

Soft tissue abnormalities can also be related to placement of the final restoration. Plaque accumulation and resultant gingival inflammation can occur when a ceramic restoration fails to vertically reach the finish line of the prepared tooth. Also, the restoration can be horizontally overextended or underextended, and both conditions lead to plaque accumulation at the margins of the restoration.

Cervical overcontouring of the restoration is a common cause of periodontal abnormalities. The enlarged dimensions may have been an oversight or a deliberate effort to improve the color by increasing porcelain thickness. In the case of a fixed partial denture, it may have been an effort to close cervical embrasure spaces. While it is often esthetically advantageous and acceptable to close a portion of the cervical embrasure space between two pontics, the area between a pontic and an abutment retainer or between individually restored teeth must be normally contoured and accessible to oral hygiene aids.

A rough inadequately glazed porcelain surface can

FIGURE 25–8

A, Temporary fixed partial denture with cervical embrasures to provide access for cleaning.
B, Lack of cervical embrasures has caused poor gingival response.

FIGURE 25–9 Poor soft tissue response to ceramic restoration. Inflammation and recession around left central incisor.

allow plaque accumulation, as can a poorly polished casting. A common area in which improper metal finishing occurs is the facial marginal area of the casting. This is particularly a problem when the metal is thinned so as to be barely visible. This small area oxidizes, and porcelain powder flows over all or part of the area during application and then fuses in position, leaving a rough irregular surface (Fig. 25–10). It is generally not possible to remove this thin layer of porcelain and to polish the metal, since grinding is extremely difficult without destroying marginal adaptation.

Occasionally teeth are encountered that possess normal soft tissue form and height but that have long epithelial attachments. There are no periodontal pockets, but some bone loss has occurred. Extreme care must

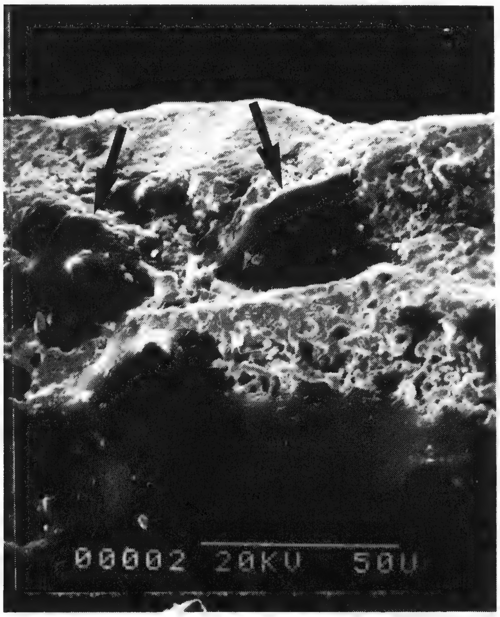


FIGURE 25–10 Scanning electron micrograph of facial finish line section of metal-ceramic crown. The collar has been thinned to a thickness of approximately 75 μm. Note the rough nature of the metal collar with presence of oxide and porcelain particles fused to metal. Magnification ×740.

be exercised in placing ceramic restorations on such teeth, since the clinical procedures may generate enough trauma to the attachment that discernible periodontal pockets can be probed after cementation of the restoration. The safest procedure is to avoid a subgingival finish line or to initiate periodontal treatment prior to tooth preparation if a subgingival margin cannot be avoided.

Early Clinical Signs and Treatment

Unfavorable soft tissue reactions generally begin in the marginal gingiva. The blood vessels in this area often become visually more apparent, and a reddened zone develops around the tooth (Fig. 25–11A). The gingival crest may even become edematous and blunted (Fig. 25–11B). If these clinical signs are detected early and are related to some previous aspect of treatment, rather than to a defect in the cemented restoration, oral hygiene procedures can be implemented that frequently prevent permanent soft tissue changes.

Sulcular brushing with a soft bristle brush and the use of unwaxed dental floss are essential. The number of brushings should be increased to several times a day until normal gingival color and form return. Thereafter, tissue health can be maintained with the usual number of brushings. The return to normal often takes a few weeks (Fig. 25–12).

Chronic Symptoms

When marginal gingival changes are not detected early, the problematic zone often increases in size, and a chronic gingival problem develops. The gingiva frequently exhibits redness and a rounded form and may recede apically. These conditions are rarely reversible, even with additional oral hygiene emphasis, and periodontal treatment may be required to prevent bone loss.

TOOTH REDUCTION

Insufficient tooth reduction is one of the major causes of poor esthetics in a ceramic restoration because the development of adequate color requires a certain thickness of porcelain. Ideally, the facial reduction should be 1 to 1.5 mm, which allows for 0.5 to 1.0 mm of dentin and enamel porcelain. Sometimes inadequate reduction is unavoidable owing to pulp size, but at times it is simply the result of failure to reduce the tooth uniformly and adequately.

When a tooth has not received adequate facial reduction, the laboratory fabrication can be handled in one of two ways. One procedure is to develop the proper contour in the restoration, which results in a lack of color vitality because of insufficient porcelain thickness. External and internal color modifications can be used to enhance the appearance of thin porcelain, but these modifications are not always wholly satisfactory solutions.

The other possible laboratory procedure, unfortunately the most common, is to develop a sufficiently thick layer of facial porcelain at the expense of normal contour. This technique provides improved color, but the restoration is overcontoured and, as a result of plaque accumulation, does not promote gingival health.

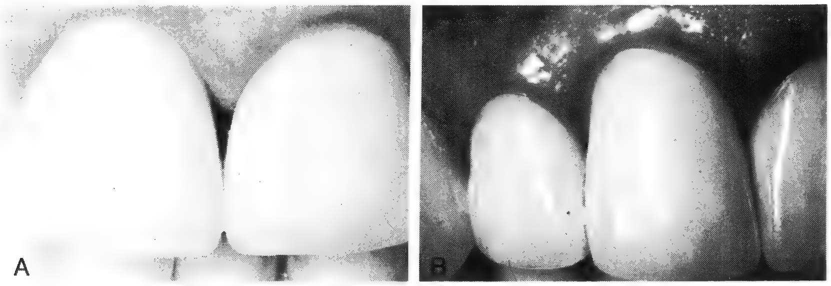


FIGURE 25–11 Early Signs of Poor Gingival Response to Ceramic Restorations

A, Slightly inflamed marginal gingiva around central incisor restorations.
B, Zone of irritation has enlarged, and gingiva is edematous with a rounded margin.

Underreduced Areas

Two areas of a ceramic preparation are commonly underreduced: (1) the labioincisal aspect of the preparation and (2) the cervical portion of the facial surface.

Insufficient reduction of the labioincisal area is generally caused by reduction of the facial surface in one relatively flat plane (Fig. 25–13). The reduction should uniformly follow the anatomic contour of the tooth, which is best accomplished by using depth cuts that follow existing facial tooth contours.

A shoulder finish line facilitates adequate cervical reduction, whereas a chamfer provides a decrease in facial reduction as the finish line is approached. In addition, the flat surface produced with a shoulder can readily be used to measure the adequacy of reduction both visually and with a hand instrument.

SHADE SELECTION

As discussed in Chapter 24, the importance of proper shade selection in a porcelain crown cannot be overemphasized. Proper coloration and shape may well be the two most important esthetic criteria for a ceramic restoration.

Many factors can be responsible for a poor color match. A poor selection may have been made from the available shades, or it may not be possible to match the natural teeth with the available porcelain colors. Also, the dental laboratory may simply have failed to reproduce a properly selected shade. If the color of the tooth varies from that of available materials, the dental laboratory may not have been furnished with sufficient color information to effect a satisfactory color modification.

There may have been insufficient overall facial reduction, or the reduction may have been inadequate in certain areas. The metal framework or opaquing porcelain, or both, may be too thick, leaving insufficient space for dentin porcelain. Also, the porcelain may not have been handled in such a manner as to reveal its inherent coloration.

COLOR VARIATIONS

Variations in color, both between different teeth and within individual teeth, can greatly enhance the naturalness of ceramic restorations. Conversely, the color uniformity of many restorations reveals their presence. It is hoped that the clinical observations and opinions described subsequently are helpful in promoting naturalness through color variation.

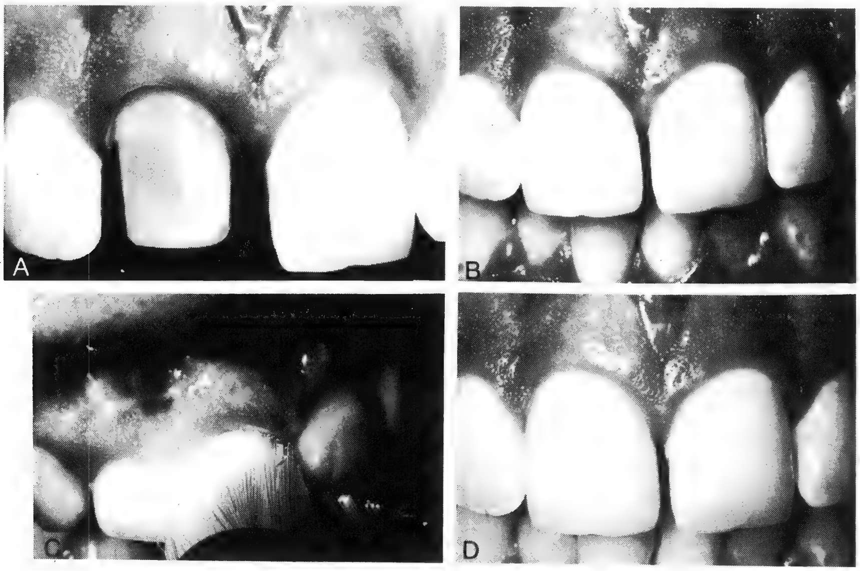


FIGURE 25–12 Treatment of Gingival Inflammation Not Related to Contour or Fit of Restoration

A, Inflammation around mesiofacial aspect of gingiva after tooth preparation and impression.
B, Inflamed area still present when restoration was cemented.
C, Sulcular brushing.
D, Gingiva has returned to normal in two weeks.

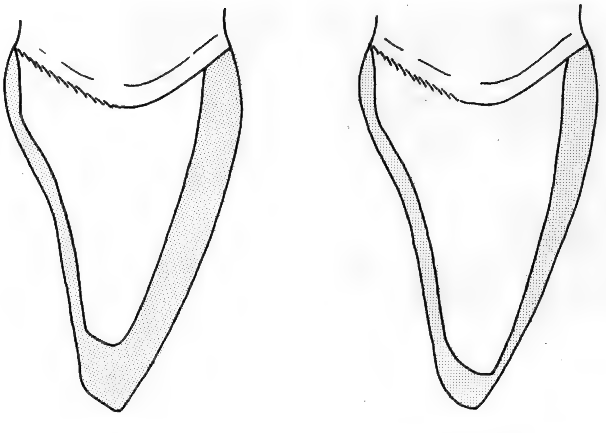


FIGURE 25–13 Correct and incorrect facial reduction of central incisor.

Variations Among Teeth

Natural maxillary anterior teeth vary in their color characteristics. Clinically, the canines are generally observed as the most intensely pigmented teeth, with the intensity related to the dentin thickness. The incisors usually appear much closer to each other in coloration. If a difference is noted, the smaller lateral incisor often has slightly less pigmentation than the central incisor (Fig. 25–14). This variation is likewise related to the faciolingual dentin thickness, which is often slightly less on a maxillary lateral incisor.

Mandibular anterior teeth also demonstrate color variation. The canines exhibit the greatest color intensity, with the incisors usually appearing the same. If a variation in the incisors exists, it is the opposite of that found in the maxillary incisors. The lateral incisor possesses the greater pigmentation owing to its larger crown dimensions.

Posterior teeth frequently exhibit approximately the same degree of pigmentation, which is less than that of the canine. Occasionally, the molars are more intensely pigmented than the premolars.

Clinical exceptions exist to all of these variation guidelines, but they can be helpful in producing a natural appearance in multiple porcelain restorations and particularly when there are not a large number of available intact natural teeth for comparison.

Variations Within A Tooth

The greatest amount of pigmentation in a tooth is usually observed cervically because tooth bulk in this area is composed of a proportionately greater amount of dentin than enamel. Incisally, the enamel is proportionately thicker than the dentin, which reduces the color intensity and increases the translucency.

The incisal thickness on canines and the cusp tip dimensions of posterior teeth cause the dentin coloration to often extend farther incisally or occlusally than on central and lateral incisors.

Different areas of coloration can be encountered within the same tooth, and no general rules can be applied to matching of such teeth. A separate shade selection is necessary for each color zone. The size of each area is measured and recorded on the laboratory work authorization form so the information can be transferred to the dental laboratory to allow different colored porcelains to be used in the appropriate areas.

The presence of resin or amalgam restorations can cause slight discoloration of adjacent teeth. It may be esthetically more pleasing to fabricate the ceramic restoration so its color resembles the slightly discolored adjacent teeth. This localized color variation may be achieved by using internal opaque and dentin modifiers or by applying surface stains, as discussed later in this chapter (Fig. 25–15).

If a tooth requires an amalgam or resin restoration, an inlay, or a partial-coverage gold restoration, it should be completed prior to the fabrication of an adjacent ceramic crown. In this manner, any change in coloration resulting from these restorations can be evaluated, and a decision can be made to match or ignore the color variation.

When it becomes necessary to match an individual porcelain restoration to severely discolored teeth, such as those with the intrinsic staining caused by tetracycline, difficulties should be anticipated as a result of the bizarre colors present and their pattern of distribution. Another complicating factor is the opalescence that is often exhibited by these teeth. The mineral opal possesses the ability to both reflect and refract light. Thus,

FIGURE 25–14 Color Variations Among Teeth

A, Mirror view of metal-ceramic restorations.
B, Facial view. Note the shade differences among the right central and lateral incisors and the canine.

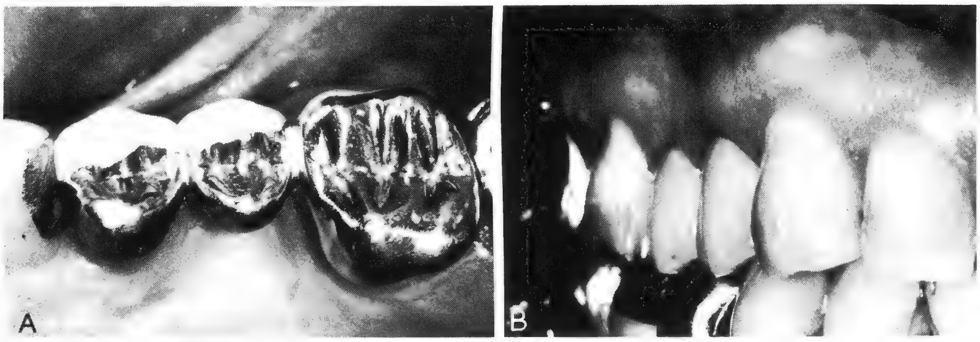


FIGURE 25–15

A, Occlusal view of metal-ceramic prosthesis. Note that the canine has an amalgam restoration, which affects tooth color.
B, The mesial aspect of the first premolar has been modified with gray porcelain to blend with the distal aspect of the canine.

the teeth often have a semitranslucent appearance but mixed with a pearllike display of color. Matching these teeth requires the use of significant amounts of colored opaque and dentin modifier porcelains, internal and external staining, and a bit of luck (Fig. 25–16). The final color match is often not completely satisfactory but better than could be achieved without the use of both internal and external color modifications. When it can be used, the porcelain jacket crown is superior to a metal-ceramic restoration, since the underlying bizarre dentin color can be transmitted through the ceramic restoration by slightly reducing the facial core thickness.

TRANSLUCENCY

The characteristic of translucency helps to give a tooth the appearance of vitality. Translucency is most obvious in the incisal portion, in which the ratio of enamel to dentin is high. Duplication or simulation of this feature is important if a ceramic restoration is to seem "alive."

The apparent translucency of a restoration is particularly important during conversation or smiling. Patients with a low smile line in which only the incisal portion of teeth is visible particularly need to have these characteristics duplicated; otherwise, the contrast between restored and unrestored teeth is embarrassingly obvious.

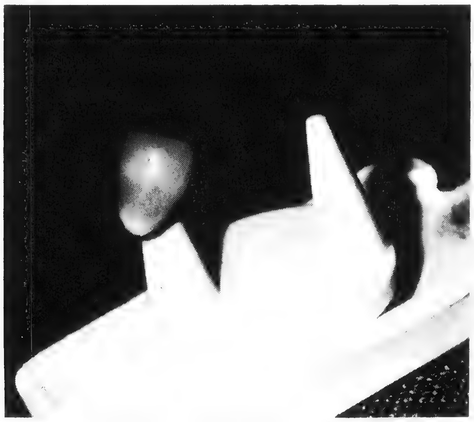


FIGURE 25–16 Opaque and dentin modifiers have been used to help simulate intrinsic staining from tetracycline.

Determining the Location and Amount of Translucency

Incisal edges, cusp tips, and proximal surfaces possess only enamel with no background of dentin, which produces areas of very high translucency. Adjacent to these areas, dentin is present, but its relative thinness allows for considerable translucency. Cervically, the translucency decreases, since there is proportionately more dentin. Generally, the transition is gradual, and translucency terminates in the incisal one-third or one-half of the crown. However, the amount of translucency varies considerably between individuals, as does its apparent termination when it is viewed facially. Some teeth have considerable translucency (Fig. 25–17A), whereas others possess little translucency (Fig. 25–17B). Likewise, the translucency terminates gradually on some teeth but rather abruptly on others (Fig. 25–17C). Because of these individual variations, it becomes necessary to clinically measure the location of translucency and to record this information on the laboratory work authorization form. Whether the translucency terminates gradually or abruptly should also be noted.

As previously discussed, laboratory fabrication involves first establishing the restoration form in only dentin porcelain and then replacing a portion of the dentin with enamel porcelain. A diagram made from clinical measurements allows the ceramist to mark the location of translucency on adjacent teeth of the working cast so the dentin buildup can be carved away according to a predetermined plan. More extensive dentin cutbacks permit greater thicknesses of enamel porcelain and more restoration translucency. If the translucency gradually decreases, the dentin cutback should terminate in a gradually tapered form, whereas an abrupt termination requires a heavy, more abrupt chamfer form (Fig. 25–18).

Areas of high translucency are frequently observed at the incisal edge and in the proximal areas, since only enamel is found at these locations. Incisally, the labial

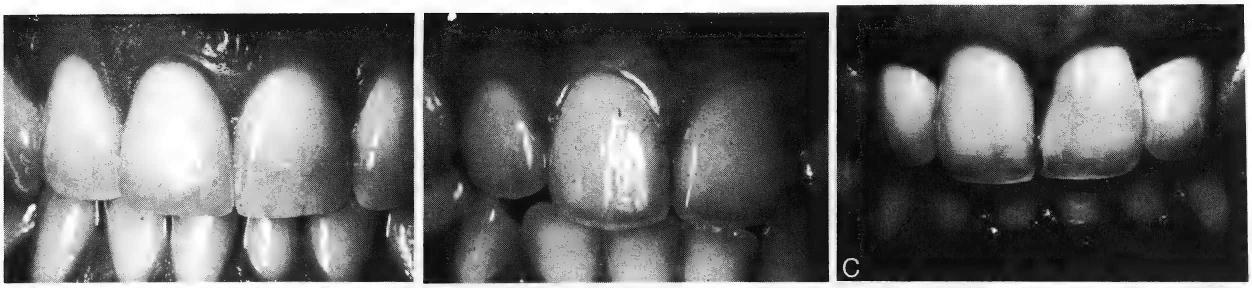


FIGURE 25–17 Tooth Translucency

A, Teeth with considerable overall translucency.
B, Teeth with little translucency.
C, Teeth with an abrupt termination of the translucency.

developmental groove depth may extend sufficiently deep that little dentin remains between the facial and lingual enamel and so that vertical lines are created with a high degree of translucency. Almost totally transparent porcelain powders can be incorporated into a restoration to simulate these areas (Fig. 25–19).

Incisal Edge Opacity

An anterior tooth sometimes has an area of slight incisal opacity. Since this area is frequently composed of only enamel, the opacity is believed to be an optical effect created by refraction of light as it strikes the incisal edge.

Reproduction of the effect can often be accomplished by shaping the incisal edge of the ceramic restoration so that it possesses the exact lingual slope and thickness of adjacent teeth (Figs. 25–19E and 25–20). Also a little surface stain, applied lingually or incorporated internally, can enhance the desired result. Unfortunately, surface stain located lingually may wear off during function.

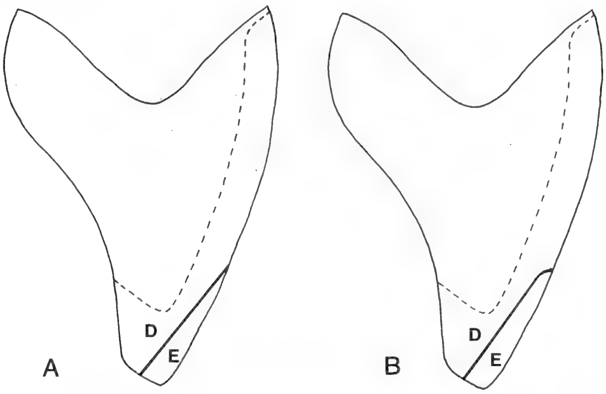


FIGURE 25–18

A, Diagram showing the form of a dentin cutback viewed proximally when gradual termination of translucency is desired. "D" indicates dentin and "E" represents location and form of enamel.
B, Diagram showing the form of a dentin cutback viewed proximally when more abrupt termination of translucency is desired.

SURFACE CHARACTERIZATION

The significance of surface texture lies in its control over the reflection of light (Fig. 25–21). When the light striking a restoration's surface creates a reflection pattern similar to that of adjacent teeth, the color match is enhanced (Fig. 25–22).

Developing the desired light reflection on a restoration's surface requires a meticulous duplication of the heights of contour and depressions on the facial surface.

Producing the desired surface characteristics requires determining their location and grinding them into the fused porcelain. The number of depressions, their location, form, and depth can be recorded by close-up photographs taken from different angles and by the working cast. In order for the cast to reproduce the required surface detail, certain procedures must be followed during impression making. The facial surfaces of adjacent natural teeth must be clean and dry, and the impression material must be syringed over the surfaces. This procedure, coupled with the use of dense vacuum-mixed stone, produces a cast with the proper degree of surface detail.

Forming the Facial Developmental Grooves

The major developmental depressions, the facial developmental grooves, should be reproduced first. It is often hard to ascertain exactly the point at which each depression begins and ends on a tooth, and this point is a key to their naturalness. Too many ceramic crowns have a definite pair of ruts that have not been blended into the surrounding porcelain.

Facial developmental grooves can be produced with a variety of different diamond instruments or abrasive stones. From the close-up photograph and cast, the mesiodistal angulation and approximate cervical termination of the grooves are determined and marked on the porcelain with a pencil.

The correct depth should be established first (Fig. 25–23A). The deepest part of the groove is generally located incisally, and there is a gradual decrease in depth as the cervical termination is approached. Next, the height of contour of adjacent tooth structure is located and marked on the cast by observing the teeth from an incisal or occlusal view. The final procedure involves producing a gradual transition from the height

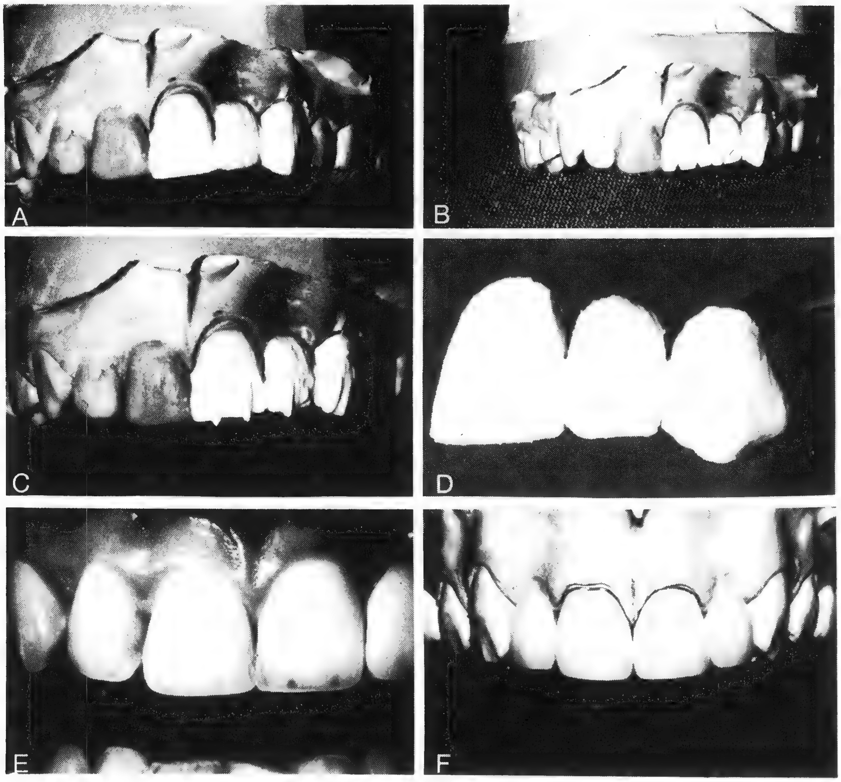


FIGURE 25–19 Transparent Porcelain Used Internally

A, Slightly oversized form established in dentin porcelain.
B, Dentin cutback with grooves and notched-out areas provided for transparent porcelain.
C, Transparent porcelain applied.
D, Enamel porcelain applied.
E, Prosthesis inserted. Note the areas of high translucency.
F, Another prosthesis on the working cast, in which vertical areas of high translucency are more diffuse in nature.

of contour to the depth of each groove. Moistening the surface with a thin film of water aids in determining whether the correct blending has been achieved.

Forming Minor Vertical Depressions

These depressions occur in random locations over the facial surface and are usually of varying lengths and depths. They are frequently more prominent on younger patients. Most, but not all, teeth possess these depressions, and therefore they should not be placed on all restorations but only on those for which clinical observation indicates their need.

The character of these depressions requires a small instrument with a sharp edge to create a fine depression. A sharp inverted cone or umbrella-shaped abrasive stone possesses the desired form.

The depth of each depression must be slightly greater

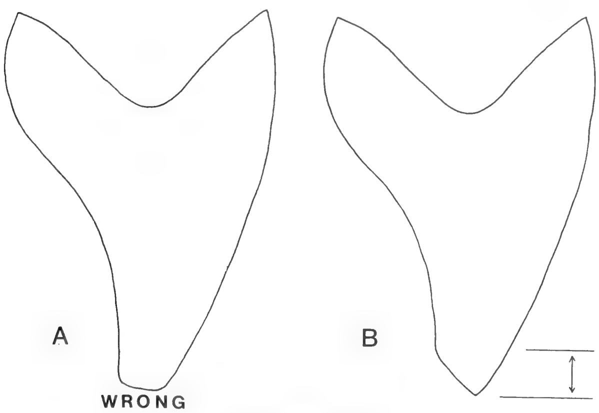


FIGURE 25–20

A, Incorrect incisal edge form.
B, Correct incisal edge form allowing zone of apparent opacity.

FIGURE 25–21 The reflection of light off surface texture.

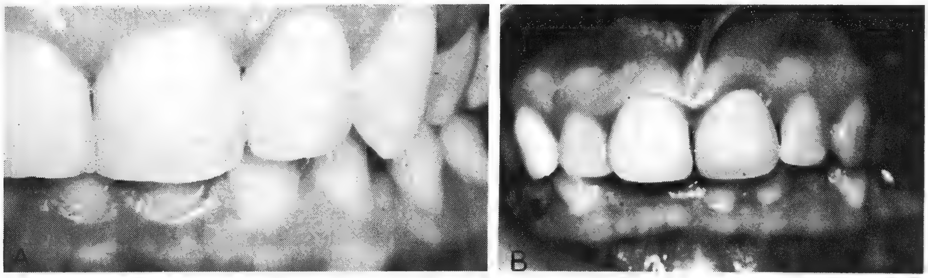


FIGURE 25–22

A, Lateral incisor restoration possessing surface characteristics similar to those of intact central incisor.
B, Left central incisor restoration lacking surface detail.

than what is desired in the glazed restoration (Fig. 25–23B). This procedure is not required for the larger facial developmental grooves but is necessary on shallower depressions, which are affected more by surface glazing. If the depressions are ground to exactly the right depth, they may become obliterated when the surface of the porcelain flows upon glazing.

Forming Minor Horizontal Depressions

Certain teeth manifest multiple horizontal lines that are rather inconspicuous during a casual observation of the tooth surface. These are also more prominent in younger patients and are best placed with a thin diamond disc and also should be slightly overaccentuated (Fig. 25–23C). The instrument is allowed to drag itself across the surface of the porcelain by its natural rotational pull. Irregularly developed lines appear more natural than uniform evenly spaced depressions.

SURFACE COLORATIONS

Finely ground pigmented porcelain powders are manufactured in many different colors for use in altering the color of a ceramic restoration (Fig. 25–24). While these materials can be used internally, they are most frequently applied to the external surface following final shaping of the fused porcelain. They can be applied over

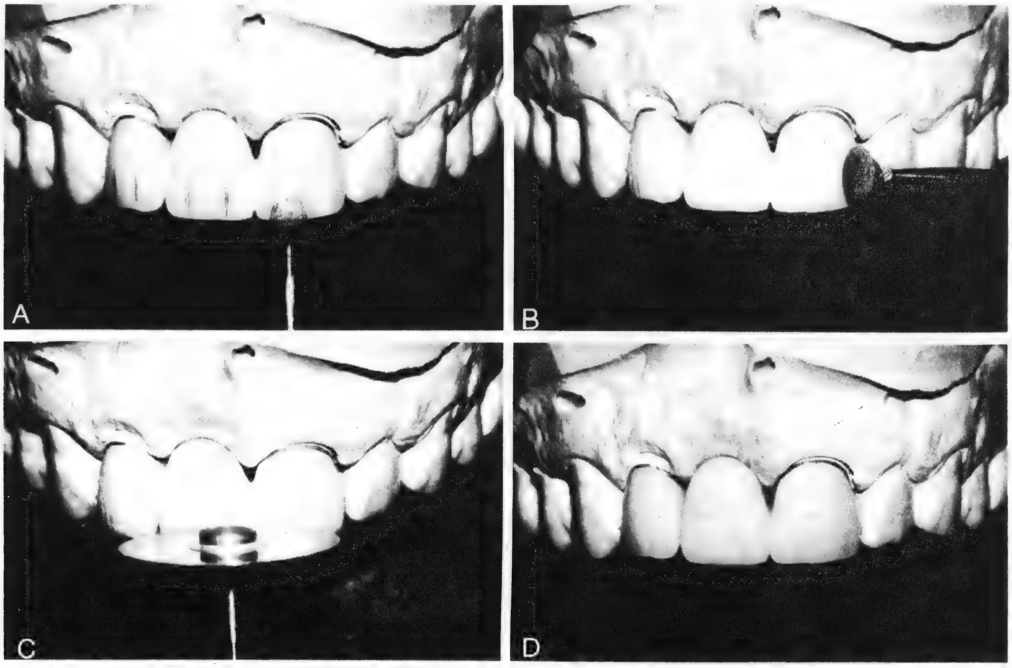


FIGURE 25–23 Surface Characterization

A, Grooves being ground to proper depth into left central incisor following locations marked in pencil.
B, Vertical depressions being formed with umbrella-shaped stone.
C, Horizontal depressions being formed with diamond disc.
D, Glazed restoration.

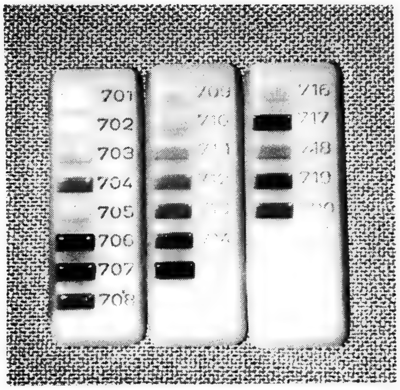


FIGURE 25–24 Different colors available in Vitachrome-L stains.*

the entire surface to create a generalized color change or restricted to localized areas for special effects. This final surface coloration is commonly called "staining the restoration."

The ability to effect color changes after the porcelain is fused, as during the clinical try-in appointment, is a valuable aid to optimizing esthetics. However, the stains must be applied properly and used within their limitations. They should not be considered a substitute for proper shade selection or as a way of overcoming improper handling of opaque, dentin, and enamel porcelains. Surface-applied stains are best used to enhance the color of a restoration and not to create the primary pigmentation, since it is difficult to disperse stains evenly over the surface in sufficient thickness to create major color changes. Also, heavily stained restorations tend to be metameric in that they match surrounding teeth under certain lighting conditions but not under others.

Application Guidelines

Most of the required surface color alterations should be accomplished prior to glazing of the restoration, since an even application of color is more easily accomplished on an unglazed surface that has an inherent texture that attracts the stain and allows its controlled application. Also, the stains become well incorporated into the molten surface of the underlying porcelain during the autoglazing procedure, ensuring greater long-term color stability.

Stains can subsequently be applied and fired over a glazed surface, but they must be used in thinner layers and often require several applications and firings to effect the desired color change. If a thicker layer of stain is applied to a smooth surface, there is a tendency for the stain to run off the high points on the surface and to pool in depressions, causing a blotchy unnatural color after the stain is fused to the surface.

The usual order of procedure is to complete the porcelain shape and surface characterizations and then ultrasonically to clean the restoration in distilled water for at least 5 minutes to remove surface debris.

Required color changes are best evaluated and accomplished by clinically seating the clean characterized restoration. Cotton rolls are positioned to prevent saliva from flowing over the porcelain surface and contaminating it. Stain liquid is applied facially and lingually to adjacent teeth to prevent their dehydration and a resulting change in color (Fig. 25–25A). This liquid is resistant to evaporation and helps contain the moisture in the teeth.

Virtually all porcelain has small pits in the ground and characterized surface, which accumulate stain. If large enough, these stain-filled pits can produce a speckled surface when the porcelain is glazed. This problem is avoided by applying a very thin layer of colorless glazing porcelain over the surface (Fig. 25–25B). This glaze should be mixed to a consistency similar to properly mixed zinc phosphate cement. When vibrated, the glaze flows into surface pits and prevents them from being filled with stain. At this stage it is possible to visualize approximately what the color of the porcelain will be like when it is glazed. Color deficiencies are noted, and appropriate stains are selected to improve the color. The effect brought about by using different colors of stain is discussed later.

The stains are mixed with the liquid provided by the manufacturer until the consistency resembles that of properly mixed zinc phosphate cement (Fig. 25–25C). A good rule is to apply a thin layer of a rather thickly mixed stain. Thinly mixed stains or thick layers of properly mixed stains are more likely to collect in depressions rather than remain evenly dispersed over the restoration surface.

When the stain application is complete, the restoration is carefully removed from the mouth by a small spoon excavator (Fig. 25–25D,E). Care must be taken to avoid contact with the facial surface, which can smear or remove the stain. The restoration is seated on a firing tray, which is placed in front of the open furnace muffle. When the stain dries, the restoration turns chalky white, and it can then be placed into the muffle and fired according to the time and temperature recommendations of the manufacturer (Fig. 25–25F).

A surface glaze is produced on the restoration simultaneously with the fusion of the stain. When the porcelain has cooled, the restoration is returned to the mouth for evaluation. Should additional stain be required, it is placed onto the glazed surface without any grinding, since this would remove previously fired surface color. The glazed surface provides less texture, which would facilitate even stain dispension. Therefore, care must be exercised to apply the stain evenly in a thin coat. The restoration is dried and fired as usual except that it is not necessary to hold the restoration at the recommended temperature unless greater surface glaze is desired.

Color Effects

It may be necessary to increase the chroma of a restoration. This is accomplished by applying a stain harmonious with the basic shade of porcelain used (yellow or reddish-yellow). If the value of the restoration is high, it can be lowered by the use of a gray surface stain. The gray stain can be applied in conjunction with a chroma-intensifying color to increase chroma and decrease value when both changes are required (Fig. 25–26).

Apparent translucency is increased by using gray,

*Vident, Baldwin Park, CA 91706.

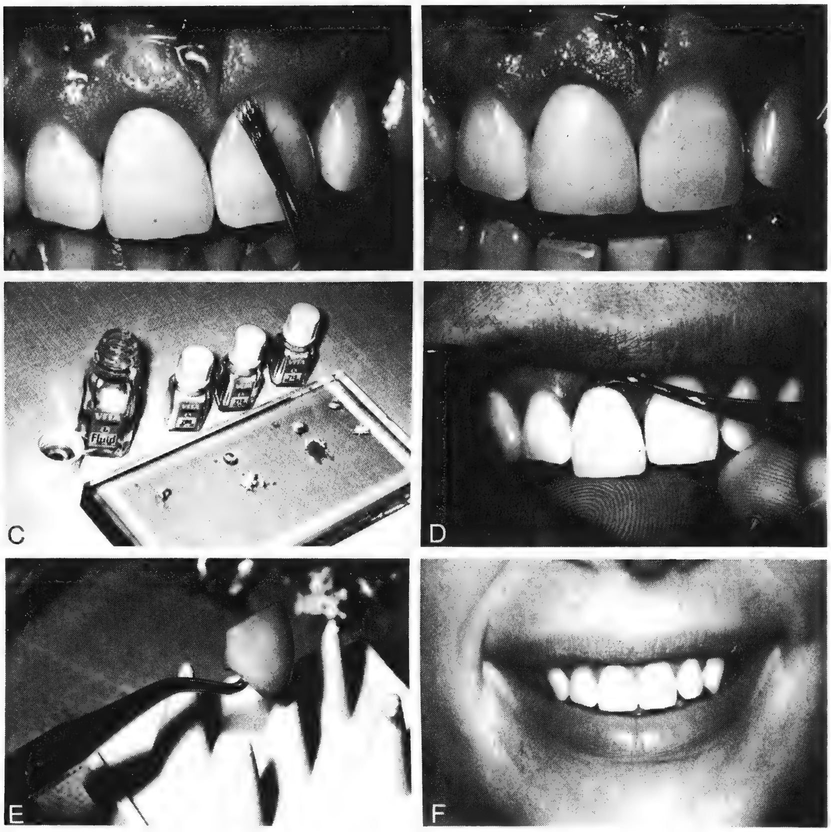


FIGURE 25–25 Surface Staining

A, Stain liquid being applied to adjacent teeth to prevent their dehydration.
B, Glazing porcelain applied to mesial portion of central incisor restoration.
C, Stains mixed on glass slab.
D, Small spoon excavator being used to remove restoration.
E, Restoration, which is inverted on excavator, is being placed on peg of firing tray.
F, Glazed restoration inserted in mouth.

blue, or violet stains. Blue or violet would be most useful on adolescent patients whose enamel translucency appears bluish rather than gray.

Stain can be applied interproximally on fixed partial dentures to enhance the illusion that individual teeth are present (Fig. 25–26B). The interproximal color present between the teeth in adjacent areas of the mouth should be evaluated and that color should be used. Dark brown, gray, and orange stains have all been successfully applied for this purpose.

Areas of decalcification may be observed on adjacent teeth. White stain is applied to produce this effect. Decalcification occurs in an irregular pattern on the surface and should be reproduced in this manner, since symmetric decalcification marks often appear artificial. It is best to place the white stain as the final step on a glazed surface on which all other color changes have been completed. This procedure allows the stain to be fused in its proper asymmetric form and not to flow over the surface as could happen if the surface were being simultaneously glazed (Fig. 25–27).

Enamel craze lines can collect stain, as is seen in

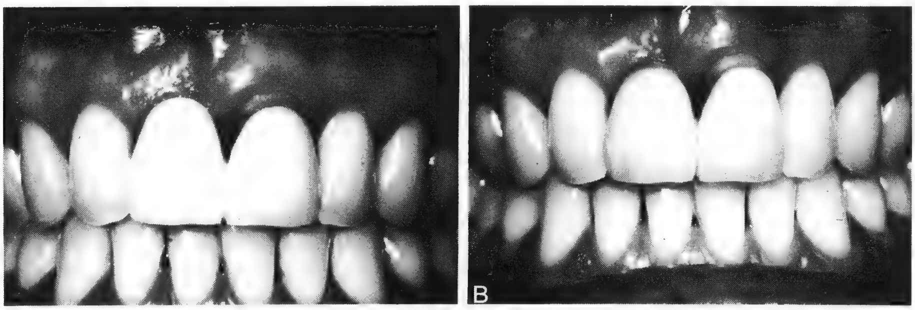


FIGURE 25–26

A, Prosthesis with inadequate incisal translucency and low chroma.
B, Gray stain has been applied to increase apparent translucency of incisal edges and interproximal areas. Yellow stain has been added cervically to increase chroma. Brown stain has been placed between central incisors to produce separation of units. Orange and brown stains were added to the cervical portion of the pontic to decrease its apparent length.

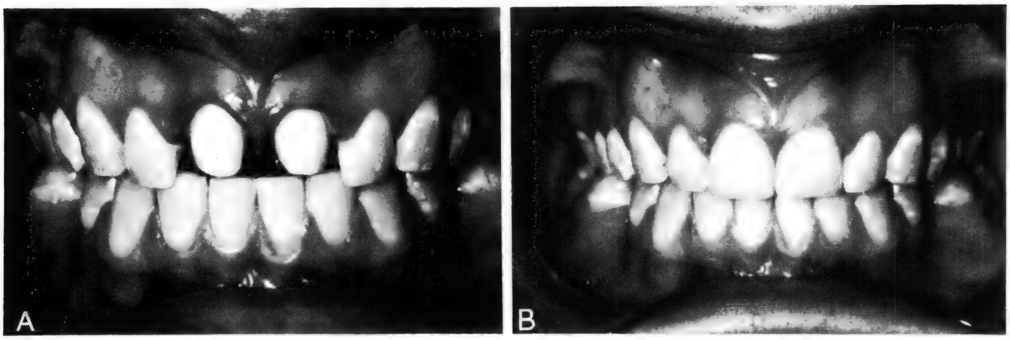


FIGURE 25–27

A, Prepared central incisors.
B, Irregular areas of decalcification produced using white stain.

some older patients. This effect is simulated by applying a dark brown stain in the form of a fine straight line. As with decalcification, it is best to place the line on a glazed surface in order to limit surface flowing and to retain the pigment in the form of a fine line.

Occasionally, it may be advantageous to simulate discolored resin restorations in adjacent teeth. While it would be best to replace these restorations with properly colored material, this is not always possible. A stain color that most closely matches the present resin color is used for this purpose. If marginal stain is present, a darker stain is used to outline the simulated resin restoration. Simulated gold foil restorations can also be placed by applying a gold powder to the surface and firing the crown to the porcelain fusion temperature. The gold is burnished with a metal instrument, and its mat appearance becomes shiny, resembling a foil restoration.

DEGREE OF GLOSS

The amount of surface gloss on the porcelain affects the reflection of light and therefore functions in conjunction with surface characterization to enhance the natural appearance of a restoration (Fig. 25–28).

A porcelain crown that has been heated during the glazing cycle for too long or to an elevated temperature can exhibit excessive flowing of the surface. In addition to the higher gloss produced, a loss of surface characterization occurs, and the surface does not scatter reflected light in the desired manner (Fig. 25–29). The excessive layer of glaze must be ground away, the surface recharacterized, and the staining and glazing procedures repeated.

Insufficient gloss can be related to factors other than glazing at too low a temperature or for too short a time. Porcelain that is poorly condensed or that has been fired too many times does not glaze as readily as well-condensed properly fired porcelain. In situations in which a porcelain crown does not autoglaze properly, a layer of overglaze porcelain must be applied.

TOOTH FORM, SIZE, AND ARCH POSITION

The full coronal restoration of a single maxillary central incisor is one of the more difficult esthetic situations encountered. Exact duplication of the shape and position of the adjacent central incisor assists in blending the restoration into surrounding natural teeth and not attracting undue visual attention. By contrast, if the restoration is slightly out of alignment with its contralateral counterpart, even though this may have been the position of the tooth before it was restored, it can become visually obvious, particularly when other aspects such as the color match have not been optimally achieved. Consequently, it is usually better for restorations to be shaped like their contralateral counterparts when they are located adjacent to unrestored teeth.

Conversely, when all of the readily visible teeth are

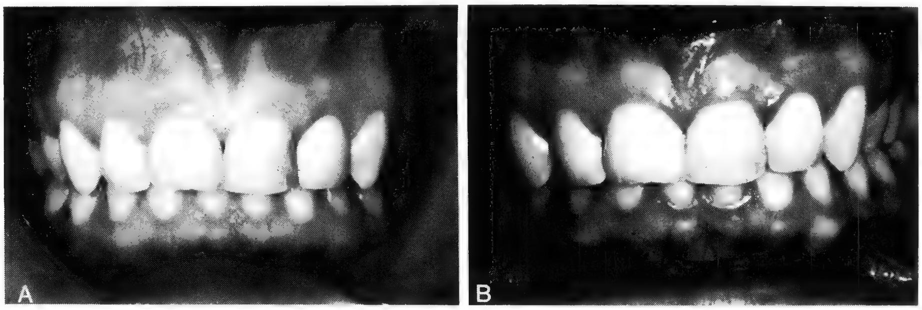


FIGURE 25–28

A, Unglazed left lateral incisor.
B, The restoration reflects light properly when it is glazed.

FIGURE 25–29
A, Overglazed prosthesis.
B, Properly glazed metal-ceramic restoration on lateral incisor.

being restored and there is no color-matching problem, it may be esthetically advantageous to create slight alterations in form and position.

Regardless of whether a decision has been made to match the contralateral tooth form or to create variations in shape, the dentist must be able to evaluate critically the restoration shape as determined by outline form, line angles, and heights of contour. This is best understood by first studying what is required to create a central incisor restoration that is a mirror image of its contralateral counterpart.

Outline Form

The correctness of the basic shape of a restoration is first determined by evaluating the outline form or peripheral contour as represented by a line drawing of the facial view (Fig. 25–30). The facial outline form can be subdivided into mesial, distal, and incisal aspects, with each surface being evaluated separately. The cervical form is controlled by the shape of the gingival tissue. Therefore, it is not included in this discussion.

The contour of the restoration should be adjusted until the mesial curvature is a mirror image of the mesial curvature of the tooth being used for comparison. The same process should be repeated for the distal surface and then the incisal edge. Reproduction of notches and mamelons in the incisal edge of the restoration adds to the natural appearance (Fig. 25–31).

The position or form of certain mandibular anterior teeth may not permit the desired incisal edge form to be duplicated in the maxillary incisor. When this can be anticipated, it is often possible to alter the mandibular incisor during preparation of the maxillary incisor. This procedure allows development of the desired form in the maxillary incisor restoration.

The last items to be verified are the proximoincisal angles, which affect the incisal embrasure size. Giving the proper size and form to each embrasure is very significant in creating a pleasing esthetic effect (Fig. 25–32A,B,C,D). A lack of incisal embrasure space causes restorations to visually appear as one unit, thereby producing an unnatural overly toothy appearance (Fig. 25–32E).

Line Angles

When two buildings are observed, the relative sizes of the buildings are visually determined by noting the distance from one corner of a building to the other. The corners of a tooth are the line angles, and while they

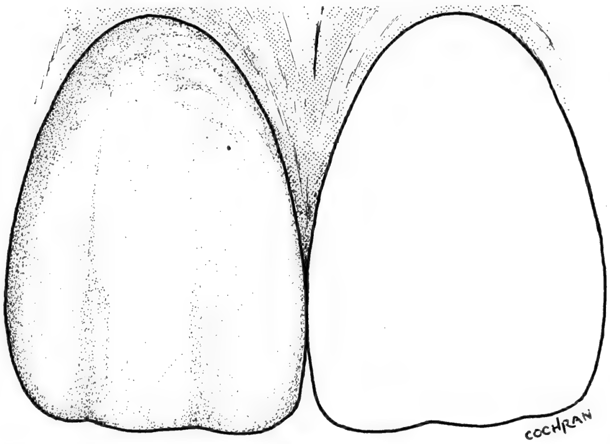


FIGURE 25–30 Left central incisor represented by drawing of outline form.

FIGURE 25–31 Right central incisor restoration contoured so that mesial and distal surfaces duplicate form of adjacent unrestored central incisor. An incisal notch has also been placed to enhance the match with the left central incisor.

FIGURE 25–32 Incisal Embrasures

A, Variations in size between incisal embrasures of unrestored teeth.
B, Size variations around canine and premolars.
C, Metal-ceramic restorations on anterior teeth showing variations in incisal embrasures.
D, All maxillary teeth have been restored with metal-ceramic restorations. Note the embrasure variations.
E, Unnatural restorations lacking incisal embrasures.

are not as well defined and are more difficult to perceive than those on a building, they still provide reference points for determining relative tooth size.

Illusions and Perceived Size

When the space that exists for an artificial central incisor is the same size as the adjacent natural central incisor, a natural appearance is achieved by placing the line angles in the same position as is found on the contralateral natural tooth.

However, when there is a size discrepancy between the restoration and the natural tooth, the line angle location and form can be used to create the illusion of a similar size.

Placement of the mesiofacial and distofacial line angles closer together produces the illusion of smaller size, since tooth structure located lingual to the line angles is less visible. In a similar manner, moving the mesiofacial and distofacial line angles farther apart produces a wider-looking restoration when the space is smaller than normal (Fig. 25–33).

Certain other effects are helpful in creating the illusion of normal size.

A flat incisal edge produces a straight line, which makes a tooth appear wider mesiodistally. Conversely, a round or notched incisal edge causes the restoration to appear smaller mesiodistally.

Forming labial developmental grooves that are distinct produces vertical lines that give the illusion of greater crown length. Just as vertical lines produce apparent increased crown length, so horizontal characterization lines produce decreased perceived crown length. A similar effect can be created in a restoration that appears too long by the creation of an obvious cementoenamel junction. This tends to separate the restoration into two smaller visual units of crown and root.

Moving the labial developmental grooves closer together or farther apart can produce a corresponding decrease or increase in perceived size, which is related to the amount of tooth structure that is visible between the grooves. With the normal tooth, the labial developmental grooves are close enough together that the central portion of the facial surface generally possesses a continuous mesiodistal curvature. When the grooves are separated, the central portion of the tooth becomes flatter, and the flat surface produces the appearance of increased size. Separation of the labial developmental grooves, decrease in their depth, and flattening of the

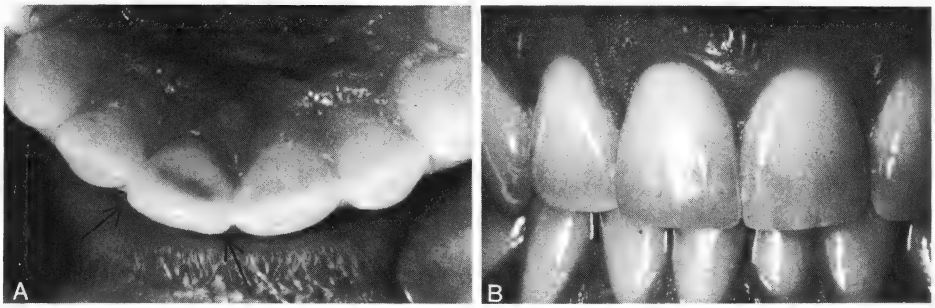


FIGURE 25–33
A, Line angles on restorations (as indicated by arrows) have been moved apart and sharpened to produce an illusion of greater mesiodistal crown dimension.
B, Facial view of restoration.

facial surface can be used together to effect a perception of increased size.

Interproximal staining of a fixed partial denture creates a line of separation between the units so that they appear as smaller more distinct entities. Proximal staining can also be used to decrease the apparent size of a single restoration by making that portion of the restoration slightly darker and thus not as apparent visually.

Some observations regarding canines and posterior teeth can also be helpful in achieving the proper size appearance when the existing space is not ideal.

The canine forms the "corner" of the mouth. The mesial portion of its facial surface is generally in alignment with the facial surface of the incisors, whereas the distal portion of the facial surface is more compatible with the posterior teeth. When a canine is observed clinically, the mesial aspect of the facial surface is usually the only portion that is readily visible, and this becomes the part of the tooth that is used in visually determining its size (Fig. 25–34).

In order to make a canine appear smaller mesiodistally, the cusp tip and facial height of contour should be moved mesially, making the mesial portion of the tooth smaller. Although the distal aspect of the facial surface becomes larger, it is not readily detectable, since that part of the tooth is somewhat hidden from visual scrutiny. Conversely, the apparent size of the canine can be enlarged by moving the facial height of contour and cusp tip distally.

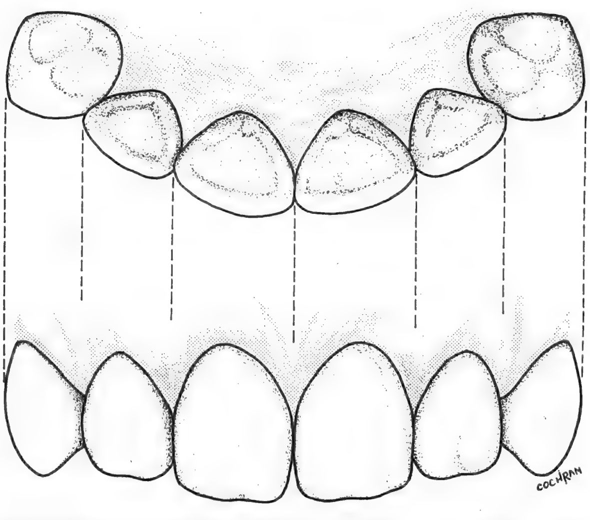


FIGURE 25–34 Diagram showing portions of anterior teeth that determine their apparent relative sizes.

These guidelines can also be applied to posterior teeth, since the portion of the facial surface mesial to the cusp tip and facial height of contour are also used in the visual determination of size (Fig. 25–35).

The judicious use of linguoversion and labioversion can also be applied to create size illusion. A tooth in linguoversion is less prominent in the arch and thus is not as readily visible. Also, part of its actual dimensions may also be covered by the adjacent teeth. A tooth in labioversion would similarly appear more prominent and therefore larger.

SUMMARY

From the previous discussion it is apparent that many factors affect the esthetic result achieved in a ceramic restoration. The most gratifying results are achieved only when careful attention is given to each of these factors.

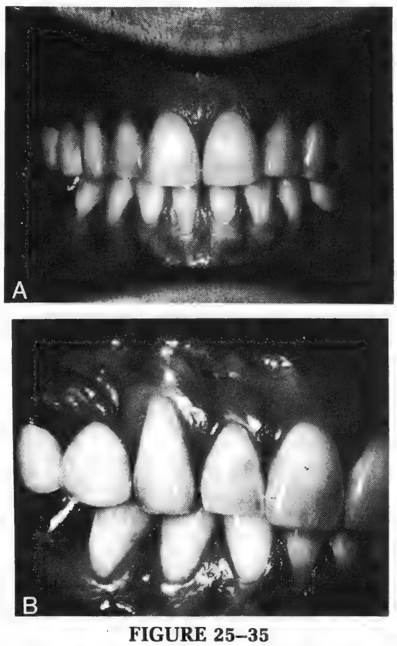


FIGURE 25–35
A, Facial view showing maxillary right prosthesis.
B, Lateral view shows excessive width of premolar, which is not seen facially, because the facial height of the contour is located mesially to the center of the pontic.

26

Resin Restorations and Resin Bonding

Jacket crowns and veneers for cast metal restorations are constructed either from dental porcelain, as has been described, or from resin. The resin that has conventionally been used is poly (methylmethacrylate) or one of the acrylic resin copolymers and recently microfilled systems. In most cases, the resins are monomer-polymer mixtures, molded under heat and pressure. Some recent formulations involve visible light–cured materials.

The principal advantages of acrylic resin when it is employed for these purposes are low cost, ease of manipulation, and ability to match tooth structure. Acrylic resin is translucent in varying degrees. This translucency imparts a natural appearance in the mouth because the resin is capable of picking up the shades of the adjoining teeth. In addition, a resin restoration is easier to fabricate than is a porcelain restoration. On the other hand, the manipulation of porcelain requires considerable artistic skill and experience on the part of the technician.

Unfortunately, the many disadvantages of the restorative resins are generally exaggerated in crown and bridge applications, as compared with their use in operative dental procedures. Because of the low proportional limit and modulus of elasticity of the resin, it must be reinforced with a metallic framework in order to resist the stresses involved in the mouth. Therefore, it is used principally as a thin veneer, or facing, over a gold alloy casting. The lack of bulk and its high ratio of surface area to volume result in a high degree of dimensional change owing to water sorption as well as from thermal fluctuations.

The acrylic resin facing does not adhere to the alloy and must be retained by mechanical means, either by cementation or by direct polymerization into undercuts of some type. However, although its adaptation may be adequate at first, its dimensional change during water sorption tends to reduce such adaptation. Furthermore, the considerable differential in the coefficient of thermal expansion between the resin and the gold alloy allows considerable percolation to occur. The result is likely to be a notable leakage between the facing and the alloy backing, which results in discoloration.

Of greater importance is the poor resistance of resin to abrasion. A resin veneer abrades rapidly under the retentive clasp arm of a partial denture, for example. Clinical experience has shown that acrylic resin veneers and crowns are often severely abraded during tooth brushing. For this reason, patients are advised to use a soft toothbrush, a nonabrasive toothpaste, and a proper brushing technique. Such patient education does not completely resolve the problem, however.

There are several types of resins employed for veneering cast gold restorations. The older conventional type of material is similar in composition to heat-cured denture resins. The dough is packed into a gypsum mold and then polymerized by heat. Some recent attempts to change the abrasion resistance have resulted in the appearance of some products containing other methacrylate monomers and small amounts of fine quartz particles or microfine silica in the polymer. Only marginal improvements in physical properties have been noted.

In summary, as compared with porcelain, the principal merits of current resins for use with fixed prostheses are ease of fabrication and cost. And, when durable and reasonably esthetic interim restorations are needed, both all-resin jacket crowns and resin-veneered metal castings can be useful (Figs. 26–1 and 26–2).

RESIN VENEERED CROWNS

The same tooth preparation that is employed for metal-ceramic restorations is recommended, since the space requirements for developing acceptable esthetics are approximately the same for both resin and porcelain.

A full-contour wax pattern is formed, and the visible facial and proximal portions of the pattern are carved away to make room for the resin. All contact in centric occlusion and eccentric mandibular movements must occur on metal to protect the resin from premature wear or breakage. The cutback pattern assumes a form similar to that of a facially veneered metal-ceramic framework except that the incisal edge is restored in metal, and mechanical undercuts are developed to hold the

FIGURE 26–1
A, Twelve-unit resin-veneered fixed partial denture.
B, Occlusal view.
C, Prosthesis seated in the mouth.

resin (Fig. 26–3). The metal extends to the labioincisal line angle.

Since none of the resins chemically bond to metal, mechanical retention must be provided. Originally, 27- or 28-gauge wire loops were incorporated into the proximal aspect of the pattern to provide this retention (Fig. 26–4). Currently, retention beads* provide the most common means of mechanical retention. An adhesive supplied by the manufacturer is painted onto the surface of the cutback patterns. The small round plastic beads are sprinkled onto the adhesive (Fig. 26–5A). When cast, the veneering surface thereby possesses many nodules for acrylic retention (Fig. 26–5B).

An opaque resin is applied to mask the metal, and then other resin is applied to simulate enamel and dentin. The resin materials are handled and shaped according to the manufacturer's instructions.

Conventional resin filling materials can be used for veneering but generally provide an esthetic result that is inferior to that obtained with materials specifically designed for this purpose.

*Acrylic retention beads, L. D. Caulk Company, Milford, DE 19963.

RESIN JACKET CROWNS

The tooth preparation and final restoration form are the same as those for a porcelain jacket crown.

The original technique for fabricating resin jackets involves investing a full-contour wax pattern in stone in a two-piece flask (Figs. 26–6 and 26–7).

A small amount of vacuum-mixed die stone is used to fill the inside of the pattern. The pattern is positioned with the lingual side down in a small mass of stone in the pattern half of the flask. The stone is carried to a point lingual to the labial line angles on the proximal and incisal surfaces so that the flash line is not visible.

FIGURE 26–2 Mandibular resin-veneered restorations.

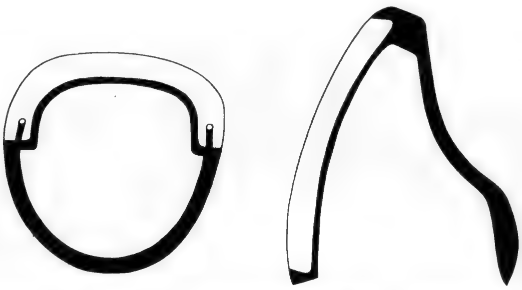


FIGURE 26–3 Form of wax pattern cutback for resin-veneered crown showing proximal retentive loops and undercuts located cervically and incisally.

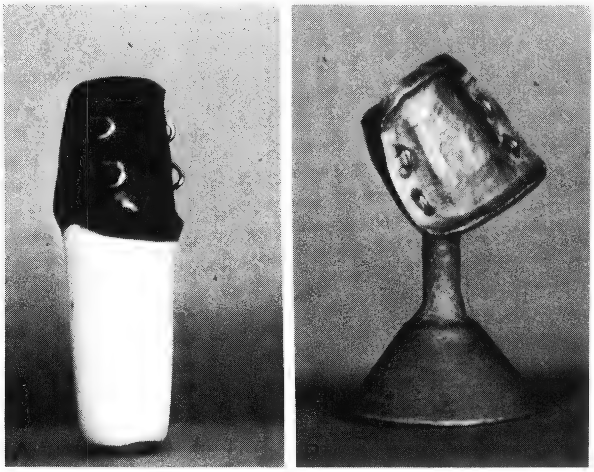


FIGURE 26–4

A, Retentive wire loops placed in wax pattern.
B, Metal cast around wire loops.

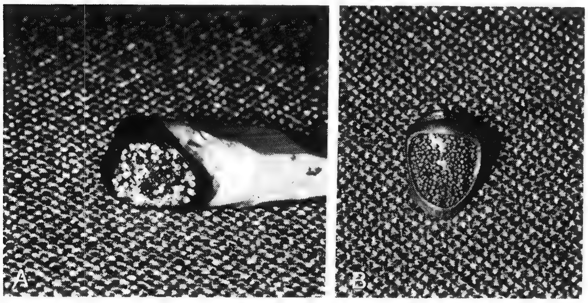


FIGURE 26–5

A, Plastic beads applied to wax pattern after cutback.
B, Metal casting.

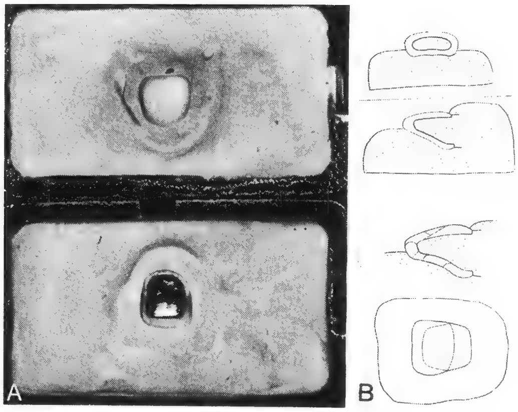


FIGURE 26–7

A, Two-piece flask separated and wax flushed away.
B, Diagram showing flasked pattern at top and incremental addition of resin at bottom.

No matter how well this line is polished, it can be detected if it is located in a visible area. At the cervical aspect, the investment is carried flush with the finish line.

After the hardened stone has been smoothed, the surface is lubricated with petroleum jelly, and the second half is poured. Any excess separating medium or air bubbles trapped on or near the pattern cause defects on the surface of the crown.

When the stone in the top half of the flask has set, the flask is warmed in hot water and opened, and all the wax is flushed away with a stream of clean boiling water (Fig. 26–7). When the flask can be held comfortably in the bare hands, the mold is coated with a resin separating medium, such as Al-Cote.*

*The L. D. Caulk Company, Milford, DE 19963.

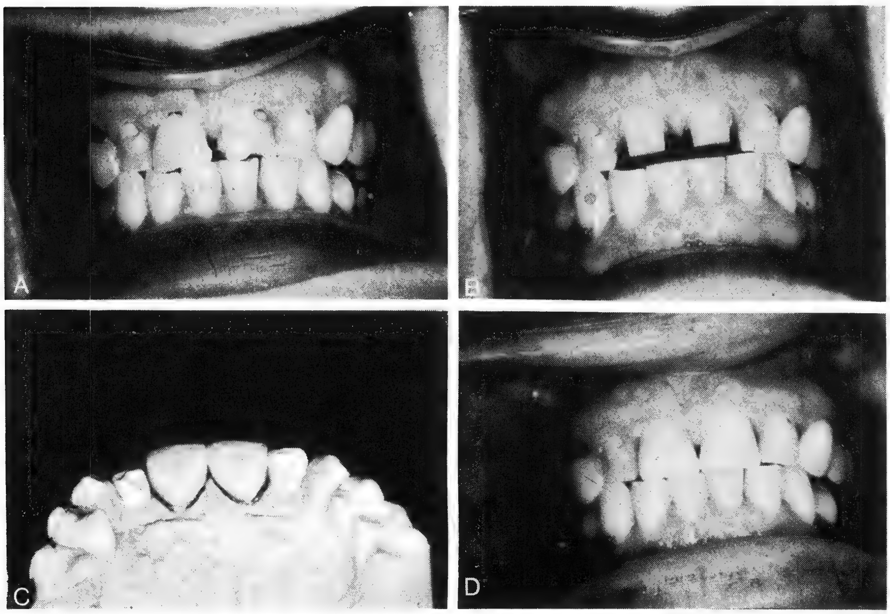


FIGURE 26–6 Resin Jacket Crowns

A, Central incisors before preparation.
B, Jacket crown preparations completed.
C, Wax patterns.
D, Completed crowns.

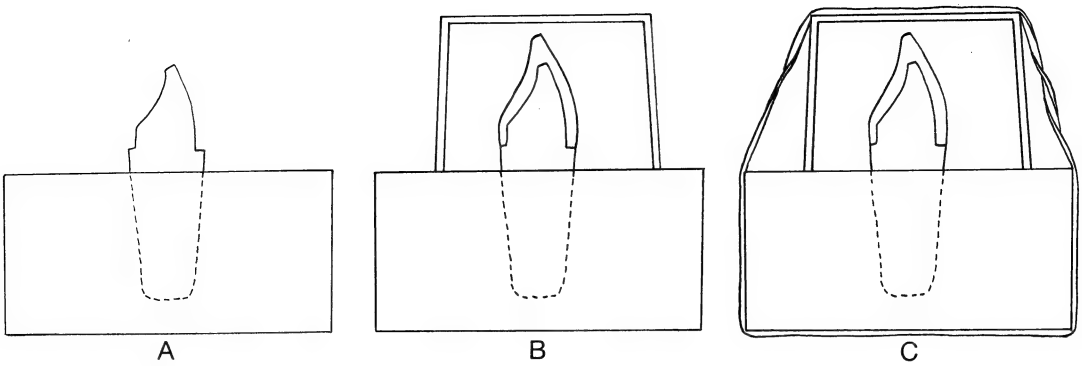


FIGURE 26–8

A, Stone die embedded in a plaster base.
B, Rubber impression obtained of full-contour wax pattern.
C, Pattern removed and impression filled with resin and reseated over die.

Next, resin is mixed and packed into the mold with care taken to properly distribute the dentin and enamel shades. This is best done by first packing the flask only with dentin and then cutting away the proper amount of dentin and replacing it with enamel resin. The resin is processed according to the manufacturer's instructions.

After processing and cooling to room temperature, the stone is removed from around the restoration with a sharp knife until it may be freed from the flask. The stone inside the crown can be partially eliminated with a small round bur inserted into the mid-portion of the material, and the remainder can be chipped away with a small pointed instrument.

The flash is cut from the crown with either small fissure burs or carborundum stones. To protect the margin, flash at the cervical area should be removed with the crown in place on the die. The restoration is polished with fine pumice in a rubber cup or with a rag wheel and a prepared resin polishing agent* to produce the final surface lustre.

Alternately, a full-contour wax pattern can be developed on the working cast. The root of a spare die is lubricated with petroleum jelly and then embedded in a stone base to within 2 mm of the margin (Fig. 26–8A). The wax pattern is seated on the die, and a rubber impression is obtained of the entire assembly (Fig. 26–8B). The wax is removed, and the die is coated with a resin separating medium. The impression is filled with the appropriate temporary crown resin, reseated, and held in position with rubber bands (Fig. 26–8C). The entire assembly is then immersed in hot water in a pressure pot to cure the resin.

The impression is removed and the cervical excess is removed carefully with sandpaper discs. The stone is ground from inside the jacket crown and then seated on the working cast for final adjustment. The usual polishing procedures are then completed.

RESIN BONDING

As an alternative to full-coverage restorations, when appearance is the primary concern, the shape and color of teeth can be changed by resin bonding procedures. The clinical and laboratory procedures relating to the use of resin bonding will not be completely covered here, but are outlined briefly because of their usage as alternatives to full coverage. An operative dentistry textbook should be consulted for detailed information. The esthetic alteration can be achieved using conventional resin restorative materials (Fig. 26–9) or by bonding a preformed resin (Fig. 26–10) or porcelain (Fig. 26–11) laminate veneer to the facial surface.

These procedures are more conservative than those for full-coverage restorations, since they often can be accomplished with minimal tooth preparation. An exception might be in the case of severe tooth discoloration that requires greater material thickness in order to mask the discoloration adequately. Even then, the usual reduction is only about 0.3 mm and terminates in enamel, allowing the preparation to be completed without local anesthesia. Resin bonding procedures are particularly useful in dealing with adolescent teeth and large pulps, because their usage avoids the amount of reduction required by conventional ceramic restorations.

Abrasion with the accompanying loss of surface texture and lustre is one of the long-term disadvantages of conventional resin restorative materials and resin laminate veneers. This problem varies greatly among individual patients and with the vigor of toothbrushing. In a severely abrasive environment the restoration may require replacement every few years whereas normally it would remain serviceable for longer periods. Porcelain laminate veneers offer the advantages of greater stability of surface texture, glaze, and color.

The resin bonding process is accomplished by the penetration of the resin into irregularities in the enamel formed by etching its surface with an applied acid.

Veneering with Conventional Resin Restorative Materials

The resin shade should be selected prior to placement of the rubber dam while the teeth are moist and possess their normal coloration. Prior to etching the enamel, trial batches of resin can be applied to the tooth and cured to ascertain the most appropriate color and even trial buildups completed to allow evaluation of shape

*Acrilustre, Buffalo Dental Manufacturing Company, Inc., Brooklyn, NY 11207.

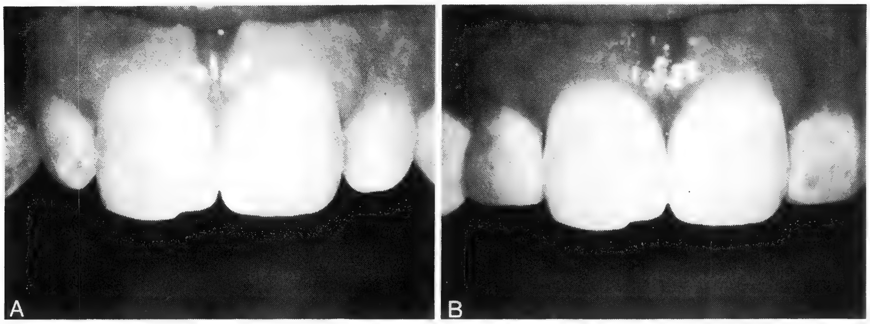


FIGURE 26–9

A, Lateral incisors prior to restoration.
B, Conventional resin restorative material has been used to improve the morphologic form of the lateral incisors. (Courtesy of M. A. Cochran.)

changes. As long as the tooth surface has not been etched, the trial materials can be easily removed with a spoon excavator.

The teeth are isolated with a rubber dam. If contour alterations necessitate placing the resin at or slightly cervical to the gingiva, it is advantageous to displace the dam and tissue cervically by using conventional gingival retraction cord or by using dental floss that has been tied tightly around the tooth and then inserted into the sulcus.

The usual acid etching procedure is then completed and either a light-activated or chemically cured resin material used to veneer the tooth. An appropriate operative dentistry textbook should be consulted for the details regarding etching and proper manipulation and finishing of the resin.

Particular attention must be paid to the cervical area in shaping and polishing the resin. The restoration should be feathered out so that a smooth transition occurs between resin and tooth, thereby eliminating or minimizing any cervical overcontouring. When possible, it is considered best to terminate the resin at the crest of the gingiva in order to avoid contact of the resin with the facial soft tissues.

Preformed Resin Laminate Veneers

Thin manufactured resin veneers* are available in several different sizes for bonding to facial surfaces. The maxillary teeth are best suited for this procedure since no occlusal interferences will be produced by increasing their faciolingual thickness and the veneers are somewhat protected from functional occlusal forces that could result in their dislodgement.

The most appropriate veneer size is selected and adapted to cover the facial surface by careful grinding and internal thinning using an abrasive stone. While the adaptation can be accomplished clinically, it is best done on a working cast, which provides better access and produces better adaptation. A heated wax spatula can be pressed against the veneer while it is on the cast, thereby adapting the veneer by thermoplastic alteration. The finalized veneer should be closely adapted to the facial surface and should extend from the labioincisal line angle to the gingival margin and into the facial proximal embrasures, extending lingually just to the facioproximal line angles. Proper coverage of the teeth is then evaluated intraorally.

Trial batches of light-cured luting resin can be used to seat the veneer if color alterations are necessary. The use of an underlying opaque resin may also be necessary to mask properly the discoloration present in some teeth.

After the appropriate resin luting material is selected, the teeth are isolated with a rubber dam. Cervical displacement of the dam and gingiva is accomplished as discussed previously. Proper displacement should provide access to the point of cervical veneer termination while the incisal aspect of the veneer is aligned with the incisal edge of the tooth. The veneers are cleaned, coated with primer, and set aside to dry.

The enamel is etched, a thin layer of the appropriate light-cured resin applied to the tooth surface and the veneer pressed against the tooth until complete seating is achieved. Clear plastic strips are used interproximally to prevent resin from bonding to adjacent teeth. The excess resin that has been expressed around the veneer perimeter is removed and the resin is cured. The marginal areas are finished as usual so that the resin feathers into the tooth cervically and a smooth, well-polished blending is achieved. The rubber dam is removed to allow final evaluation of the gingiva-resin relationship. Should additional contouring or finishing be necessary, retraction cord can be used to displace the gingiva to avoid trauma from the rotary instruments.

Preformed Porcelain Laminate Veneers

Porcelain veneers can be placed either with or without tooth reduction, but there is less cervical overcontouring and less chance of fracturing the thin friable veneer

*Mastique Laminate Veneers, L. D. Caulk Co., Milford, DE 19963.

FIGURE 26–10
Preformed resin laminate veneers placed over discolored maxillary incisors. (Courtesy of D. R. Avery.)

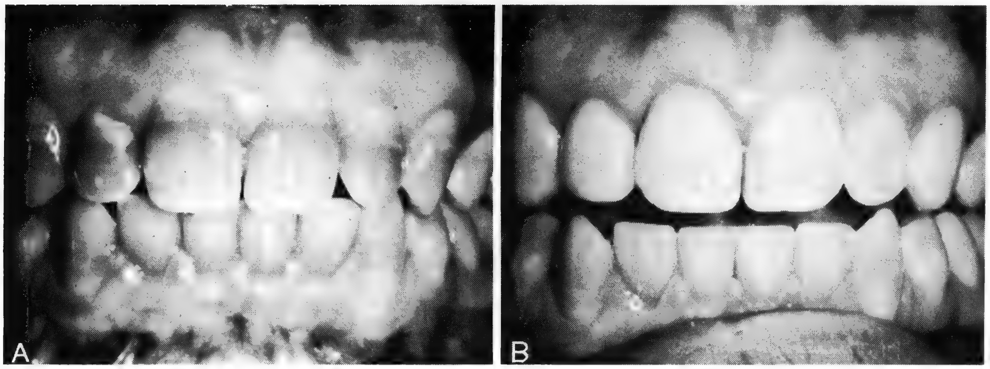


FIGURE 26–11

A, Patient with severely discolored teeth.
B, Porcelain facial veneers have been placed on maxillary anterior teeth. (Courtesy of D. R. Avery.)

margins when the facial surface has been reduced about 0.3 mm and a definite peripheral finish line has been established.

The shade is selected using any conventional ceramic shade guide. The tooth is prepared as required, a full arch impression obtained, and a stone cast poured. Since the veneers are fabricated by fusing porcelain directly onto a refractory investment,* an impression must be poured using the refractory material. While the usual full arch impression could be repoured in investment, the friable nature of the investment may cause teeth on the cast to fracture upon removal from the impression. For this reason it is best to obtain a second impression for the purpose of producing the refractory cast. This second impression should include only the facial surfaces of the teeth to be veneered. A material that possesses long-term dimensional stability such as poly (vinyl siloxane) is recommended since this impression may be poured more than once by the dental laboratory technician.

The investment cast is trimmed to remove as much excess material as possible and decontaminated by firing in an oven according to the manufacturer's instructions. After the cast has returned to room temperature, it is placed in distilled water for a few minutes so that the mixed porcelain will not be prematurely dried by the dehydrated cast. A very thin mixture of opaque and dentin porcelains is first applied to the veneer area and fired at the usual opaque firing temperature. One part of opaque to four parts of dentin has been suggested as a starting point, with more opaque being needed if the tooth is severely discolored. The final form is then completed using dentin porcelain. Enamel porcelain can be used but only a minimal effect is possible since the total veneer thickness should be no more than 0.5 mm. Multiple firings will be necessary to fill in the cracks that occur during firing of the initial full contour buildup. The veneer is shaped, the marginal areas refined, and the porcelain stained and glazed using the refractory cast.

The veneer is carefully separated from the cast after wetting the investment to make it more friable. An air abrasive unit with 50 micrometer aluminous oxide is used to remove residual investment. Some marginal refinement will likely be necessary when the veneers are adapted to the working cast.

The facial surface of the veneer is coated with sticky wax and a bar of wax attached to the surface to serve as a handle. The veneer is then immersed in a sealed plastic container of hydrofluoric acid for one minute to etch the porcelain surface and provide retention for the resin which will be used to lute the veneer to the tooth. The veneer is removed from the acid, thoroughly rinsed in water, and the sticky wax removed. Alternately, the veneer can be immersed in a hydrofluoric acid substitute for a longer period of time (approximately 3 minutes).

The same procedures and materials used for insertion of resin laminate veneers are used with porcelain veneers. Extreme care must be used during the trial insertion and bonding procedures to prevent fracture of the thin friable porcelain margins.

*V. H. T. Investment, Whip Mix Corp., Louisville, KY 40217.

27

Restoration of Mutilated and Pulpless Teeth

The presence of caries, restorations, trauma, or a combination of these conditions can cause teeth to have little intact coronal tooth structure remaining (Fig. 27–1) so that difficulty may be encountered in developing adequate retention on structurally sound material.

Auxiliary retention, such as is obtained with pinholes and grooves, can be added to that gained by the preparation of the remaining tooth structure. However, replacement of the missing tooth structure with a separate restoration that is not part of the prosthesis is a better method of achieving adequate retention. A separate restoration is advantageous for several reasons: (1) if it is well anchored into remaining tooth structure and made of a sufficiently strong material, the resulting normal preparation dimensions allow the restoration to exhibit better resistance to occlusal forces; (2) a separate restoration eliminates thick areas in the wax pattern that have a tendency to be porous when cast; (3) subsequent removal of the prosthesis, if necessary, can be accomplished more easily with less risk of irreversible damage to remaining tooth structure; (4) a separate restoration with an underlying base material can often protect the pulp from thermal changes more effectively than if the missing tooth structure is part of the final casting; and (5) it is easier to retain a temporary restoration when normal preparation dimensions have been achieved.

FIGURE 27–1 Traumatically injured teeth with considerable loss of coronal tooth structure.

Rebuilding of teeth so that subsequent preparations assume normal dimensions can be accomplished by several different techniques, depending on whether the extensively damaged teeth have vital pulps or endodontic treatment is necessary. However, in either case, the final preparation must be extended onto sound tooth structure, thereby reducing the possibility of tooth fracture.

REBUILDING VITAL TEETH

Missing coronal tooth structure that is needed for retention or that produces undercuts in the preparation should be restored before the impression is obtained.

The selection of the restorative material must include consideration of the size and location of the irregular area. Defects close to the finish line are best restored with a material such as amalgam that is known to provide a good long-term marginal seal. When large areas of tooth structure are missing and retention must be provided by that part of the tooth, a strong filling material or cast metal is required. However, if the defective area is small, not in proximity to the finish line, and not needed for the retention and resistance form of the preparation, cement provides an easy and effective material for filling the defect.

Dental Cement

Any dental cement can be used to fill small defects or undercut areas in a preparation. However, polycarboxy-

FIGURE 27–2 Polycarboxylate cement used to restore defects in preparations.

late cement has advantages that should be considered. It is nonirritating to the pulp, exhibits some adhesion to tooth structure, and can be prepared to a smooth surface after hardening (Fig. 27–2). The placement of mechanical retention to augment the adhesion ensures that the cement is not dislodged during clinical procedures.

Amalgam and Pin-Retained Amalgam

Amalgam is an excellent material for filling small or large defects so that normal preparation form is achieved (Fig. 27–3). It must be mechanically retained in the tooth, and the retentive features must be placed sufficiently deep that subsequent tooth preparation does not eliminate these areas and dislodge the amalgam. When possible, the restoration should be placed prior to tooth preparation, particularly if a matrix band is required, since it is difficult to retain a band on the tooth once it is prepared.

Amalgams require more time to develop adequate hardness than does cement and generally must be placed at one appointment with the tooth prepared at another appointment. Recently, however, some high–copper-content spherical amalgams have been developed that have relatively high early strengths and that can be prepared at the same appointment.

When considerable tooth structure is missing, the usual parallelism and mechanical undercuts in the prepared tooth do not adequately retain amalgam, and auxiliary retention is required. Pins, anchored in dentin, have been used extensively and successfully for many years to provide the needed retention. The resulting preparation composed of tooth structure and pin-retained amalgam provides a good prosthesis foundation. Both self-threading pins* (Fig. 27–4) and cemented pins have been used for this purpose.

FIGURE 27–3 Preparation defects restored with amalgam.

FIGURE 27–4 Self-threading pin placed into extracted tooth.

Cemented pins (Markley wire) have only experienced limited usage but may be advantageous in endodontically treated teeth (this procedure is discussed later in the chapter). The pins are slightly smaller than the drill used to prepare the channel and are serrated. The pin is cemented in position, and the amalgam is condensed around the pins.

Self-threading pins are slightly larger than the drill used to make the holes and create their own threads in the dentin as they are screwed into place with a holding device that is similar to a miniature wrench (Fig. 27–5). The pins crush and deform dentin, and if the elastic limit of dentin is exceeded, craze lines develop. Enamel crazing can also occur. The technical procedures involved in placing self-threading pins deserve discussion, since improper technique increases the incidence of discernible tooth crazing.

Drilling Pinholes

Prior to drilling of pinholes, a decision must be made regarding the number of pins required for proper retention and the diameter of the pins.

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*TMS pins, Whaledent International, New York, NY 10001.

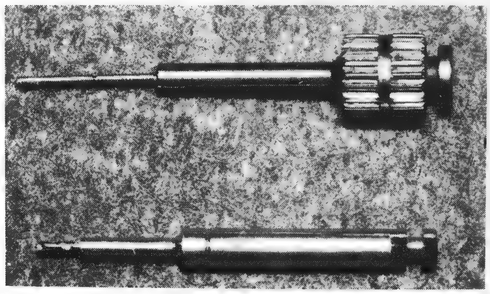


FIGURE 27–5 Bottom, Drill used to place pinholes. Top, Self-threading pin in holding device.

Four pin diameters are available from the manufacturer, with the proper size being determined by evaluating tooth structure dimensions and the functional forces that will be applied to the restoration. Wherever occlusal forces are likely to be heavy, the pin rigidity of the two largest diameters (0.76 and 0.60 mm) is required (Fig. 27–6). The size of the largest pin (0.76 mm) often restricts its use to molar teeth, whereas the 0.60-mm pin relates well to most of the anterior and posterior teeth commonly encountered in fixed prosthodontics. The 0.48- and 0.37-mm pins do not provide adequate rigidity and retention for a restoration that must support a fixed prosthesis.

A rule that can be used to determine the number of pins is to place one pin per missing peripheral surface (facial, lingual, mesial, and distal), with a maximum of four pins per tooth. Problems with inadvertent perforation into the pulp or periodontium are more likely when a large number of pins are placed, since satisfactory locations in a tooth are limited.

The location of the required number of pins is based on a thorough knowledge of crown and root morphology. The pins should be placed in thick portions of the tooth without large crown or root concavities located cervically to the selected area. The middle of the proximal surface is a poor location on many teeth, owing to concavities commonly located in this area (such as the mesial surface of the maxillary first premolar). Another poor location is over a furcation. Flat areas should be prepared at the pinhole sites, since drilling on an inclined plane is very difficult.

The hole should be positioned away from the periphery of the tooth and well into sound tooth structure. A guideline for a tooth that is to be prepared subsequently for a full-coverage restoration is to leave at least 1 mm of dentin lateral to the pinhole (Fig. 27–7). The angulation of the drill is determined by probing the form of the tooth cervical to the pinhole location and holding the drill parallel to this surface (Fig. 27–8).

The drill should be rotated slowly and the hole drilled to a depth of 2 mm, while the alignment is maintained with a solid finger rest. When a depth of 1 mm is reached, the drill is lifted out of the hole so accumulated debris can escape and not interfere with further drilling. The drill is returned to the hole, and the final depth is established.

A sharp drill efficiently removes dentin without undue

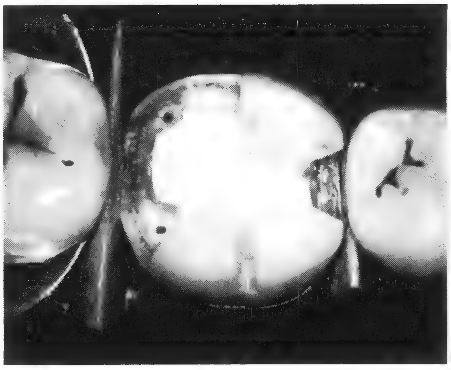


FIGURE 27–7 Pinholes drilled 1 mm inside dentoenamel junction. (Courtesy of M.A. Cochran.)

pressure. Forceful drilling with a dull instrument can result in tooth crazing, excess heat generation, or fracture of the drill in the tooth. A dull drill can and should be sharpened by using the side of a fine-grit diamond disc or separating disc to regrind the end bevels.

If drill fracture occurs, another pinhole is placed with no attempt made to remove the fractured drill segment unless it projects well above the tooth and can easily be grasped. A new pinhole should not be placed closer than 2 mm to a previous pinhole in order to prevent a communicating crack between the two.

Pinholes that perforate into the periodontal ligament space or pulp pose problems that require further treatment. If a lateral perforation occurs occlusally to the periodontal attachment, it may be possible to extend the finish line cervically and cover the defect (Fig. 27–9). When the perforation penetrates into the attachment, periodontal surgery should be performed so the defective area can be smoothed off or restored with amalgam (Fig. 27–10). Some perforations are surgically inaccessible and require the extraction of the tooth. Perforation into the pulp necessitates endodontic treatment. If either situation occurs, the amalgam restoration should be completed to provide a stable interim restoration.

Placing the Pins and Amalgam

The pins can be screwed into the tooth by hand or by use of a special gear reduction handpiece (Fig. 27–11).

FIGURE 27–6 Four sizes of self-threading pins. (Courtesy of M.A. Cochran.)

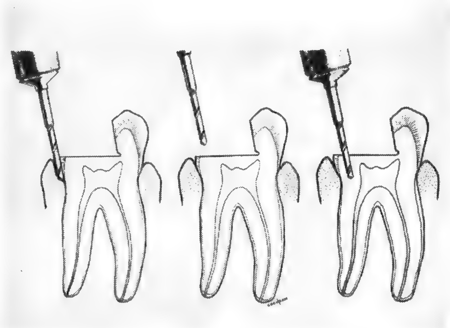


FIGURE 27–8 Drill being used to probe lateral tooth form to determine angulation of pinhole. (Courtesy of M.A. Cochran.)

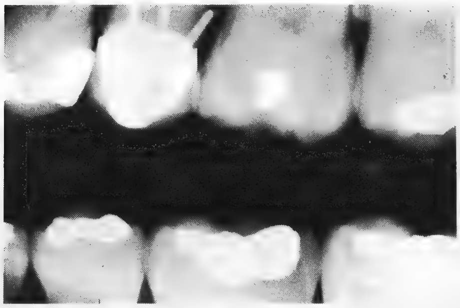


FIGURE 27–9 Lateral pin perforation located occlusally to periodontal ligament.

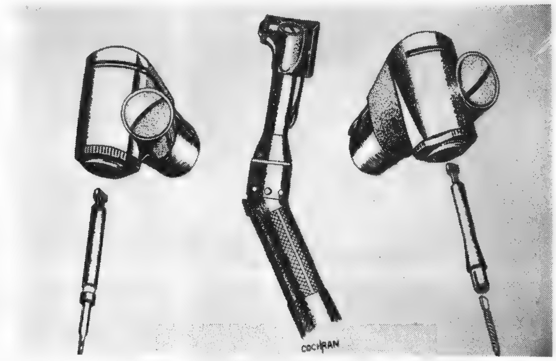


FIGURE 27–11 Gear reduction handpiece used to drill holes and drive pins into pinhole. (Courtesy of M.A. Cochran.)

Both procedures provide adequate placement, but hand insertion allows better tactile feeling that aids in verifying proper depth placement and retentive grasp into the dentin. The pins are slowly screwed into the holes until they are fully seated (Fig. 27–12A). If additional force is then applied, tooth crazing often occurs. Self-shearing pins are available, which shear off at a predetermined stress level to prevent excessive force development.

It is generally necessary to bend the pin toward the center of the tooth so that subsequent tooth preparation does not expose the pins. A special notched instrument (TMS Bending Tool) is available for careful and slow bending of the pin (Fig. 27–12B,C). Extensive bending should be avoided, since the pin can fracture. In addition, the pins are often too long and require shortening so that they do not interfere with the occlusion or subsequent tooth reduction. A high-speed diamond instrument is used to shorten the pin until about 2 mm projects above the tooth. The pin should be held with cotton pliers or the bending tool during cutting to avoid its loosening.

The matrix band is placed and the amalgam is carefully condensed around the pins and carved as usual (Fig. 27–12D,E). The crown preparation is then completed.

Resin and Pin-Retained Resin

Coronal tooth form can be rebuilt with resin or pin-retained resin restorations using the same procedures as with amalgam (Fig. 27–13). An advantage of resin is that it hardens rapidly and can be prepared shortly after placement. Resin is indicated for esthetic reasons when anterior teeth must be rebuilt for future full-coverage restorations. Also, the color of the underlying prepared tooth often affects the color of a porcelain jacket crown, and it is advantageous to use resin to rebuild normal preparation form.

In comparing large pin-retained resins with large pin-retained amalgams, the authors have observed considerably more mechanical failures when prostheses were cemented over pin-retained resins (Fig. 27–14). These failures involved loss of retention, often with accompanying caries and resin fracture.

FIGURE 27–10 Pin perforation into periodontal ligament.

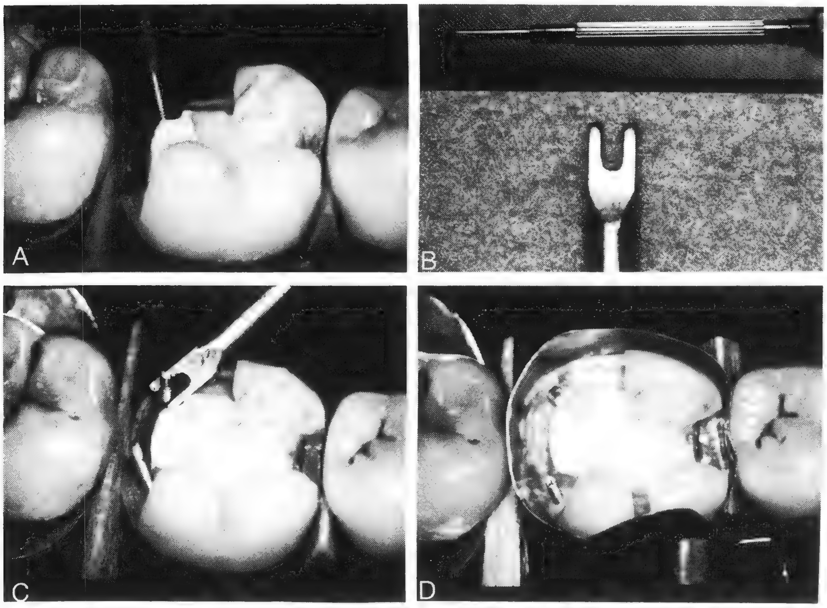
Pin-Retained Cast Core

A cast core can be used to restore small or large areas but is particularly indicated on badly broken down teeth for which maximal material rigidity is required. The casting is cemented to the tooth to provide excellent support for the overlying prosthesis.

The clinical procedures are as follows. First, the desired tooth preparation form for the prosthesis is developed on the remaining coronal tooth structure, and the location and depth of the finish line is established. Grooves are placed as needed to augment casting retention. Pinholes (2.0 mm deep) are then prepared in the tooth. The number of pins and their location is based on the guidelines discussed for pin-retained amalgams. Since the pinoles must be parallel to each other, their alignment is critical. They are placed to the proper depth using a number ½ round bur at slow speed and then finalized using a slowly rotating number 700 bur.

An impression is obtained by using a Lentulo Spiral instrument to ensure that the rubber impression material is deposited to the base of each pinhole. Stone is poured into the impression to obtain a working cast (Fig. 27–15A). Tapered plastic pins* that fit the pinholes are shortened as required, and the cast is lubricated (Fig. 27–15B). The pattern is waxed to create ideal preparation form, and a casting is made using a Type

*Williams plastic pins, Williams Gold Manufacturing Company, Buffalo, NY 14214.



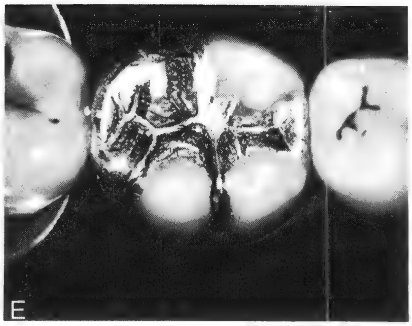


FIGURE 27–12 Pin-Retained Amalgam
A, Pin being driven into pinhole.
B, TMS bending tool.
C, Tool being used to bend pin.
D, Both pins shortened and matrix band in position.
E, Amalgam restoration carved. (Courtesy of M.A. Cochran.)

IV alloy (Fig. 27–15C,D). If desired, appropriate nongold alloys can be used.

The casting is then cemented to the prepared tooth. After the cement has set, the tooth preparation is finalized.

REBUILDING NONVITAL TEETH

Type of Restoration Required

Some endodontically treated teeth are intact except for the prepared access opening to the root canals. When this situation exists on single anterior teeth that are not discolored, a resin restoration can often be placed in the access opening with no further treatment necessary (Fig. 27–16). The same situation on posterior teeth generally necessitates the cementation of an extracoronal cast restoration to prevent tooth fracture, since the morphologic form and location in the mouth of these teeth elicits forces that attempt to push the cusps apart. Endodontic treatment appears to increase the potential for tooth fracture under these forces. Full-coverage restorations provide the best resistance to expansion, although partial veneer crowns can adequately encompass the tooth in certain situations.

When an abutment tooth is endodontically treated and is intact except for the access opening, the amount of tooth structure remaining after tooth preparation must be carefully assessed. If only a thin peripheral shell of tooth remains after reduction (which occurs frequently on incisors, canines, and premolars), a cast post and core should be fabricated. A *post and core* is a restoration consisting of a post that fits a prepared root canal and a core inserted into the pulp chamber that

FIGURE 27–13 Pin-retained resin restoration.

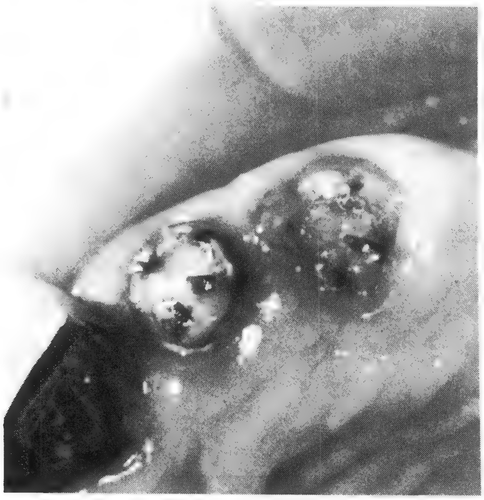


FIGURE 27–14 Clinical failure, the result of prosthesis placed over pin-retained resin cores.

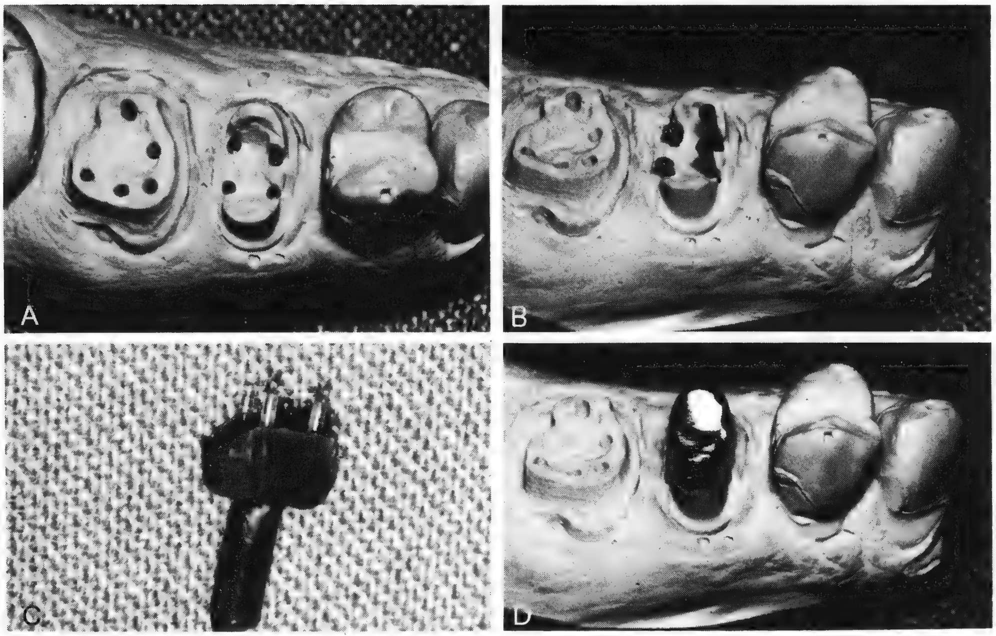


FIGURE 27–15 Pin-Retained Cast Core

A, Working cast of teeth prepared for pin-retained cast cores.
B, Tapered plastic pins inserted into pinholes. Distal pins have been shortened.
C, Sprue former attached and pattern ready for investing.
D, Finished casting.

also establishes the proper coronal tooth preparation form (Fig. 27–17). The post and core is made with a rigid material which, when cemented into the root canal and pulp chamber, provides a solid foundation restoration that is well retained in the tooth.

Some endodontically treated abutment teeth, although previously restored, possess sufficient tooth structure that an adequately strong foundation can be created with conventional amalgams or pin-retained amalgams. Molar teeth most commonly fit into this category.

The clinical procedures for placing pin-retained amalgams in nonvital teeth are the same as those described for vital teeth except that self-threading pins may not be indicated. Teeth that have been endodontically treated for several years exhibit more crazing when self-threading pins are inserted into the dentin than that which occurs with vital teeth or recently devitalized teeth. When such teeth are encountered, cementing of pins into holes slightly larger than the pin reduces crazing. Serrated wire designed for cementation can be used, or self-threading pins can be cemented into holes deliberately enlarged to prevent binding.

It is difficult to identify exactly when the limitations of pin-retained restorations have been exceeded and

FIGURE 27–16 Endodontically treated central incisor, which can be adequately restored by using resin in the access opening.

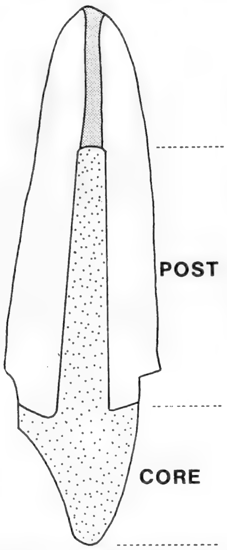


FIGURE 27–17 Cross section of post and core in tooth.

FIGURE 27–18 A tooth that was fractured during athletic competition restored with a post and core.

when retention should be gained from the pulp chamber and root canal by fabricating a post and core. However, guidelines relating to the amount and quality of remaining tooth structure are helpful. A safe rule to follow is that when more than one-half of the abutment tooth axial surfaces will be composed of a pin-retained restoration, a post and core should be fabricated. Also, if only thin walls of tooth structure remain after tooth preparation (1 mm or less in thickness), a post and core is indicated.

When evaluating the need for a post and core, the lifestyle of the patient also deserves consideration. If possible, a post and core should be avoided for individuals, such as athletes, who are susceptible to subsequent traumatic tooth injury. A serious blow to a restoration with an underlying post and core frequently results in root fracture and necessitates extraction of the tooth (Fig. 27–18). Without the presence of a post and core, the fracture is more likely to occur at the level of the finish line, so that a new restoration can be inserted. Even if a post and core is required for retention of the new prosthesis, at least this treatment has made it possible to retain a strategic tooth through one more traumatic injury.

Under no circumstances should a post that is to be cemented into the root canal be an integral part of the restoration, since removal of the restoration, if necessary, often is not possible without damage to the tooth.

Types of Posts and Cores

A post and core can be made entirely from one material (cast metal) or a combination of two or more materials such as a metal post cemented into the root canal with amalgam or resin built around it. When amalgam or resin is used, smaller cemented or threaded pins are placed into dentin to augment retention and prevent rotation of the post and core (Fig. 27–19). A post and core that is an integral rigid cast unit is preferred as the foundation for a fixed partial denture.

Posts may be either slightly tapered or have parallel sides, with retention dependent on cemention into the root canal. Also, there is one type of parallel-walled post that is threaded and depends primarily for its retention on being screwed into a slightly undersized prepared canal. Unfortunately, this procedure may initiate crazing, which could lead to fracture of the root and failure of the restoration. However, the threaded post may be the best choice when root length is insufficient to provide enough retention for a conventional cemented post.

Preparation Guidelines

Ideally, the root canal should be prepared to accept the post during or immediately following the endodontic treatment by the operator who filled the canals and is aware of the existing root morphology. In this way, the optimal length and diameter of the post space can be created without excessive dentin removal or root perforation. Many endodontists currently provide referring dentists with prepared post spaces. They also provide information regarding aberrant root forms that do not permit the development of larger post dimensions and a warning against further enlargement. This is the ideal method of post preparation, but unfortunately it is not always possible.

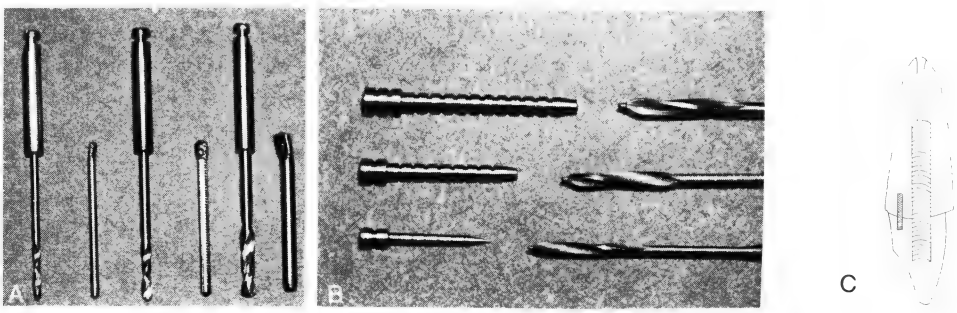


FIGURE 27–19 Metal Post Systems

A, Para-post System* placed next to corresponding drills.
B, BCH† post system with corresponding Peeso reamers.
C, Cross section of tooth rebuilt with metal post, threaded pin, and restorative material.

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*Whaledent International, New York, NY 10001.
†Unitek Corporation, Monrovia, CA 91016.

Coronal Tooth Preparation

Prior to post and core construction, the full-coverage preparation form should be established on the remaining coronal tooth structure (Fig. 27–20A,B). Then the post and core preparation is completed (Fig. 27–20C). This order of procedure reduces the amount of tooth preparation that must be performed after the post and core is cemented and allows an accurate assessment of the strength of the tooth structure that remains after the preparation form is established. The alternative is to fabricate and cement the post and core and then prepare the tooth for the prosthesis. This technique presents problems in that thin tooth structure adjacent to the core may fracture during preparation and leave irregular undercut areas that must be eliminated. Also, the final preparation often requires reduction of the casting. This reduction is hard to complete efficiently, smooth surfaces are difficult to achieve, and tooth fracture may occur from the pressure and vibration transmitted through the post and core to the tooth.

The tooth preparation should include removal of remaining amalgam or resin filling materials, since they generally do not contribute to retention of the final prosthesis and removal allows accurate assessment of the supporting and retentive characteristics of remaining tooth structure. The finish line, even on badly broken down teeth, should be extended cervically onto at least 1 to 2 mm of sound tooth structure. This extension may necessitate a subgingival finish line or periodontal surgery to expose additional intact tooth structure. A prosthesis that engages sound tooth structure reduces the possibility of circumferential tooth expansion and fracture when occlusal forces are applied.

Root Canal and Pulp Chamber Preparation

If the root canal has been previously prepared for a post, undercuts may still be present between the path of insertion dictated by the prepared root canal and the remaining prepared coronal tooth structure. These types of undercuts can easily be eliminated by further preparation of the tooth. However, if the required reduction is extensive and would weaken the tooth, the undercuts should be blocked out by filling them with a dental cement.

If the post space has not been completed, it should be prepared prior to elimination of coronal undercuts. Hand instruments provide the safest method of removing root canal filling materials and avoiding root perforation (Fig. 27–21A). With gutta-percha, a hot instrument (such as an endodontic spreader) easily removes the required amount of material. Hand files can then be used to enlarge the canal.

The prepared post space should be enlarged at least to that of a size 100 endodontic file to allow for adequate post thickness. If root dimensions permit, enlargement to a size 120 file provides additional casting rigidity. Very large canals can be safely prepared to a size 140 file. Ideally, the post preparation should be no wider than one-third the width of the root with 2 mm of tooth structure surrounding the prepared channel.

Rotary instruments are also used to remove the endodontic filling material and prepare the root canal. They must be carefully used on all roots but particularly those possessing concavities, since perforation with rotary instruments can occur rapidly. Definite end cutting instruments such as round burs easily create their own channel. This channel presents no problem if the instrument is held at the right angulation and is frequently removed to verify that the proper course is being followed. However, in inexperienced hands, a bur can wander with tragic results. For this reason, the preferred instruments are those with noncutting points that more readily follow the root canal filling material (Gates-Glidden drills and Peeso reamers) (Fig. 27–21B,C). Some individuals prefer the Gates-Glidden drill because of its more flexible shaft, which has less of a tendency to

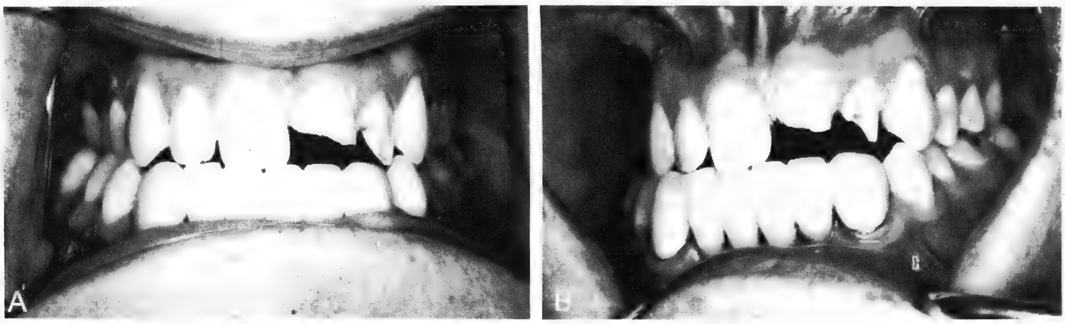
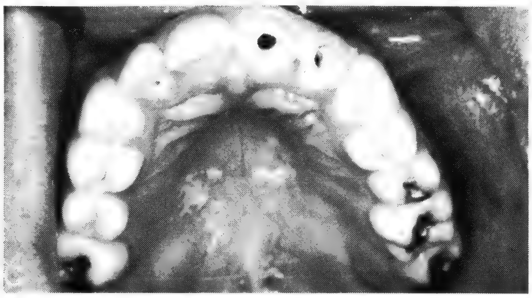



FIGURE 27–20 Tooth Preparation Sequence

A, Fractured teeth after endodontic treatment.
B, Preparation form established.
C, Post space created.

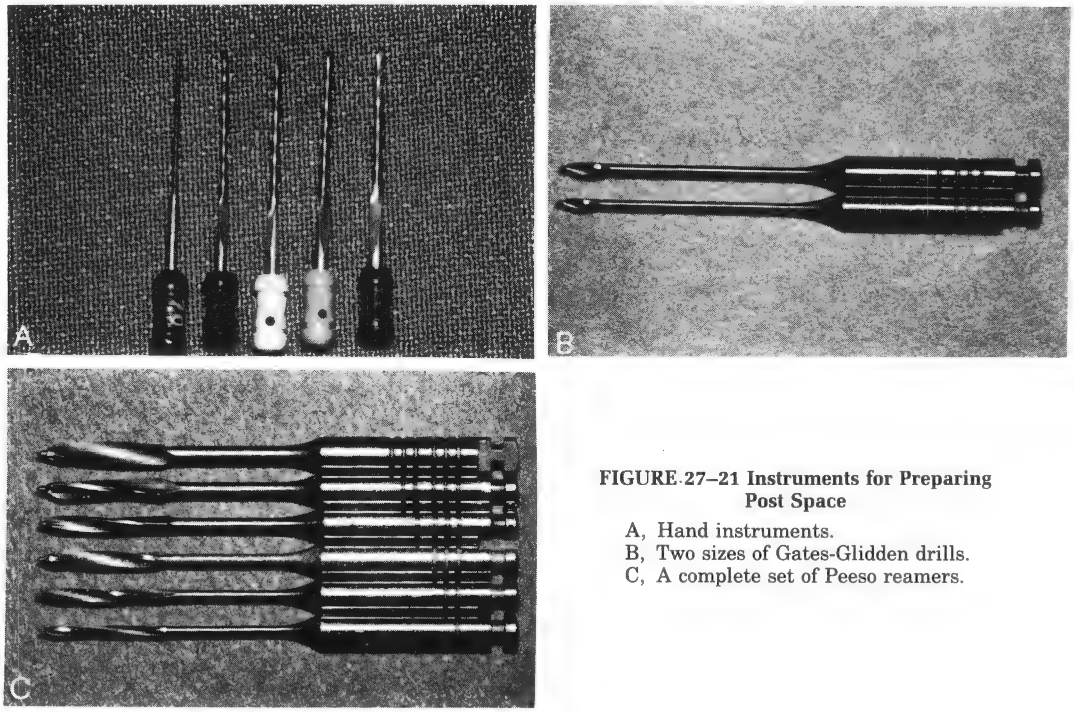


FIGURE 27–21 Instruments for Preparing Post Space

A, Hand instruments.
B, Two sizes of Gates-Glidden drills.
C, A complete set of Peeso reamers.

wander from the root canal pathway. Regardless of the instrumentation used, the filling material must be removed slowly with frequent visual verification that the root canal is being followed. The enlargement must be centered around the canal to minimize the chances of perforation.

Silver points and paste filling materials present problems in preparing post space, since they are difficult or impossible to adequately remove while a good apical seal is maintained. Teeth with these types of filling materials should be retreated with gutta-percha prior to prosthodontic treatment if a post and core is needed.

The length of the post preparation is determined by two guidelines that sometimes conflict with each other. Minimally, the post should extend into the root canal the same distance that the final restoration will project above the finish line (maintaining a one-to-one relationship) (Fig. 27–22). Short posts that fail to achieve this relationship often loosen during function, resulting in dislodgment of the overlying restoration, caries, or both (Fig. 27–23). Second, 5 mm of gutta percha remaining apically ensures that the seal of the filling material is not compromised. However, in certain teeth, one or both of these guidelines may have to be slightly altered to achieve successful post and core restorations.

The preparation should include features that provide resistance to rotation. The form of some root canals yields a round preparation with little resistance to rotation, whereas other canals are elliptic and in themselves possess an antirotational form. When the round form is encountered, a groove (at least 2 mm long) is placed into the occlusal aspect of the prepared post space.

After the canal preparation is completed and the path of insertion established, any coronal undercuts are removed or blocked out.

Fabrication Techniques for Cast Posts and Cores

Cast posts and cores can be accurately fabricated in several ways. The casting pattern can be formed directly on the prepared tooth or indirectly on a cast obtained from an impression. Generally, post and core patterns for posterior teeth are best handled indirectly, whereas they can be developed directly on many anterior teeth. The pattern can be formed entirely of wax or resin, or a wax or resin core may be built around a metal post. With the second type of pattern, molten alloy is cast directly around the metal post with the two interlocking to produce a rigid structure.

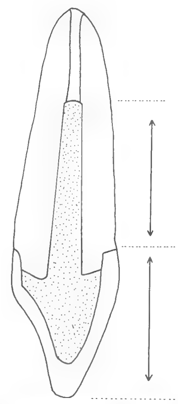


FIGURE 27–22 Cross section of post and core in tooth

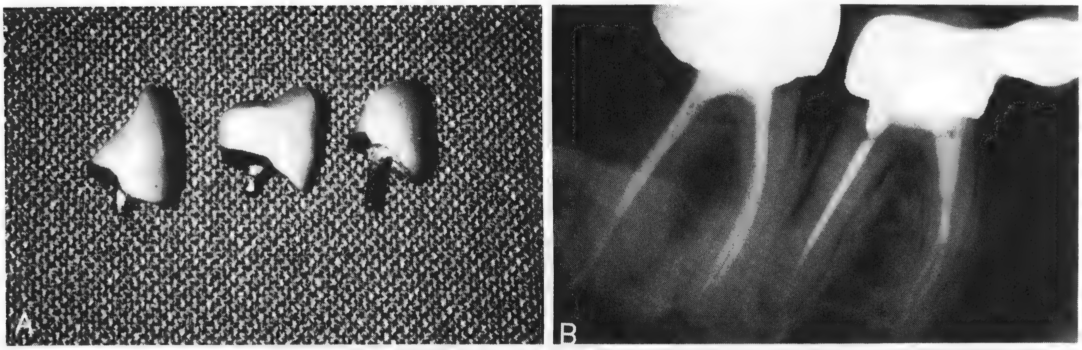


FIGURE 27–23 Post and Core Failures

A, Short posts that resulted in clinical failure.
B, Loss of retention followed by caries in mandibular first molar as a result of a short post.

Direct Pattern Fabrication

Wax Pattern

The most difficult aspect of direct wax pattern formation is the complete retrieval of the wax when it has been carried to the bottom of the prepared root canal. Intact removal usually requires the use of a stiff structure around which the wax can be applied and to which it adheres. A thin plastic sprue former or plastic post pattern* that fits into the prepared canal can be used for this purpose.

The prepared root canal is lightly coated with die lubricant. Wax is applied to the reinforcing structure, which is then seated into the canal while the wax is soft. The addition of small increments of wax, beginning apically and progressing occlusally as successive increments are applied, helps ensure intact retrieval.

Wax is applied to form the core, and the pattern is carved to the desired shape (Fig. 27–24). It is then ready to be invested.

*Endowel, Star Dental Products, Valley Forge, PA 19482.

FIGURE 27–24 Direct wax pattern formed around plastic post pattern. (Courtesy of M.R. Lund.)

Resin Pattern

A plastic sprue former or plastic post pattern is selected and trimmed to fit loosely in the prepared root canal (Fig. 27–25A). Notches are placed in the incisal aspect of the plastic pattern to facilitate good interlocking with the resin. Acrylic resin* is mixed to a thin consistency in a dappen dish, and the lubricated root canal is filled with resin by using a cement instrument (hand applied or of the rotary Lentulo Spiral type). The plastic pattern is coated with monomer and seated into the root canal (Fig. 27–25B).

Complete attention must be paid to the progression of resin polymerization in the tooth. As the resin begins to stiffen, the plastic pin is grasped, and the resin is moved slightly in and out of the root canal. As the resin stiffness increases, the post is completely removed and reseated until no binding exists between the tooth and the post. This procedure is mandatory to ensure that the resin does not lock into small undercuts, which are often present in prepared root canals or pulp chambers. When this technique is used, particular caution must be exercised by inexperienced individuals.

If small voids are observed when the resin pattern is removed from the tooth, a soft wax can be used to fill in the depression and the post can be reseated. Additional resin is then added by the bead-brush technique to establish a slight excess of material for a core (Fig. 27–25C).

The completely polymerized resin core is prepared to the desired form with the usual rotary instruments (Fig. 27–25D). The pattern is then ready to be invested and cast.

Preformed Metal or Plastic Post and Direct Pattern Buildup

A manufactured metal† (Fig. 27–26A) or plastic‡ post (Fig. 27–26B) that accurately fits the prepared root canal can be placed into the tooth. The post should be notched occlusally so good interlocking with the core material

*Duralay, Reliance Dental Manufacturing Company, Worth, IL 60482.
†Endo Post, Kerr Manufacturing Company, Romulus, MI 48174.
‡Endowel, Star Dental Products, Valley Forge, PA 19482.

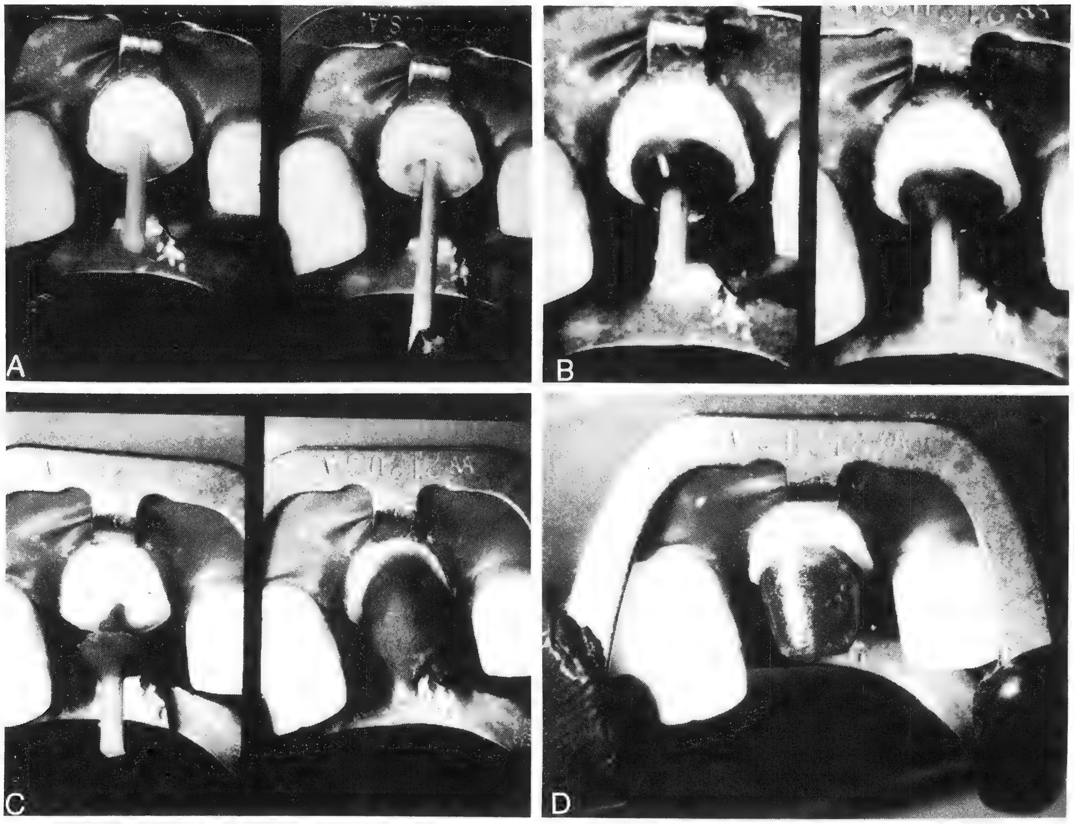


FIGURE 27–25 Direct Resin Post and Core Pattern

A, Left, Plastic post pattern placed in prepared canal. Right, Incisal portion of canal orifice has been prepared to create an irregularity to resist rotation.
B, Left, Resin placed in canal and post seated. Right, Resin beginning to stiffen.
C, Left, Pattern removed from tooth. Right, Additional resin applied to establish core.
D, Core prepared after complete polymerization of resin. (Courtesy of M.R. Lund.)

can be achieved. The occlusal aspect of the post adaptation and the core form is completed by using wax or resin as previously discussed. The pattern is then invested and cast. When a metal post has been used, molten alloy is cast around the post, which mechanically interlocks with the previously developed notches to produce a rigid structure. When a plastic post is used, the pattern completely burns out, and the post is formed entirely in the casting alloy.

Indirect Pattern Formation

Post and Core Impressions

Impressions can be obtained of any tooth prepared for a post and core, but indirect procedures are particularly indicated for posterior teeth to which direct access is restricted.

Various rubber impression materials can be used to obtain the impression. Poly (vinyl Siloxane) materials

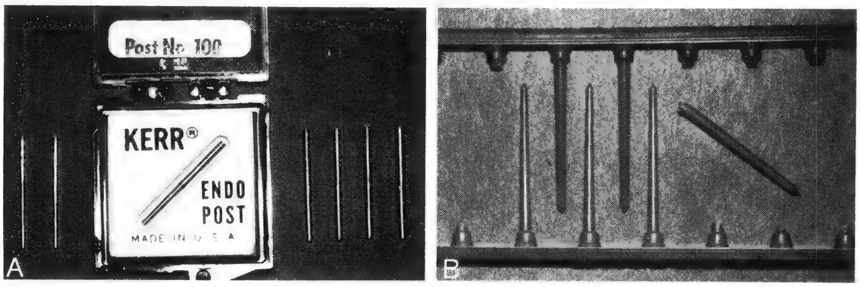


FIGURE 27–26

A, Kerr Endo Posts.
B, Star Endowels.

are especially effective because they are relatively stiff and exhibit little adherence to the prepared tooth.

The canal should be lubricated when polysulfide materials are used, but this is not necessary with other materials that have little adherence. A slight film of moisture can be left on the prepared tooth surfaces, or a thin film of die lubricant can be applied. Non–water-soluble materials such as petroleum jelly should not be used, since complete removal of the lubricant may not be possible and its presence could affect cement retention.

It may be necessary to support the rubber material that is placed into the canal. This process is necessary for taking impressions of divergent canals and also helps prevent stone from displacing the post portion when the impression is poured. A section of metal from a safety pin, which is not easily distorted, serves as an excellent support material. The metal should be notched and coated with the appropriate adhesive. Plastic post patterns and paper clips have also been used for this purpose. Support for the impression material is particularly important when a long thin root canal is present. The pin must be shortened occlusally so that it does not contact the impression tray and cause displacement of the pin.

The mixed rubber impression material is deposited to the base of the prepared canal by a slowly turning Lentulo Spiral instrument (Fig. 27–27A). If a support is used, the pin is seated through the impression material to the full depth of the post preparation (Fig. 27–27B). A syringe is then used to place impression material around the prepared coronal surfaces (Fig. 27–27C). The tray is positioned and held steadily until the impression material manifests sufficient stiffness that it cannot be distorted. When the impression material has set properly, the tray is removed along the path of insertion of the prepared root canal to minimize impression distortion (Fig. 27–27D).

Vacuum-mixed dental stone is poured into the impression to obtain the working cast. The cast is trimmed and mounted as usual.

A pattern can be formed on the working cast by any of the techniques discussed previously under direct pattern formation, although wax is generally preferred to resin because it is readily manipulated in the laboratory with less chance of damage to the stone cast.

A preformed plastic post, properly related in size to the instrument used for the post preparation, forms an excellent pattern around which wax can be added to achieve the required adaptation (Fig. 27–28A). A plastic pin can sometimes be selected to fit the canal properly, but, wherever needed, molten wax can be applied to the plastic pin to improve the adaptation.

A suggested technique for achieving proper adaptation is to apply a small amount of wax to the most apical section of the pin that is not well adapted. While the wax is soft, the pin is seated into the lubricated canal, and an orientation mark is placed on the pin with a hot instrument so the pattern can be properly reoriented. Excess wax is displaced occlusally, and an area of good adaptation is achieved. Additional wax is added in small increments, and the process is repeated until the entire post is properly adapted (Fig. 27–28B). Additional wax is added to establish the core form (Fig. 27–28C). After the wax has hardened, the core is carved to be confluent with existing prepared coronal tooth structure. The

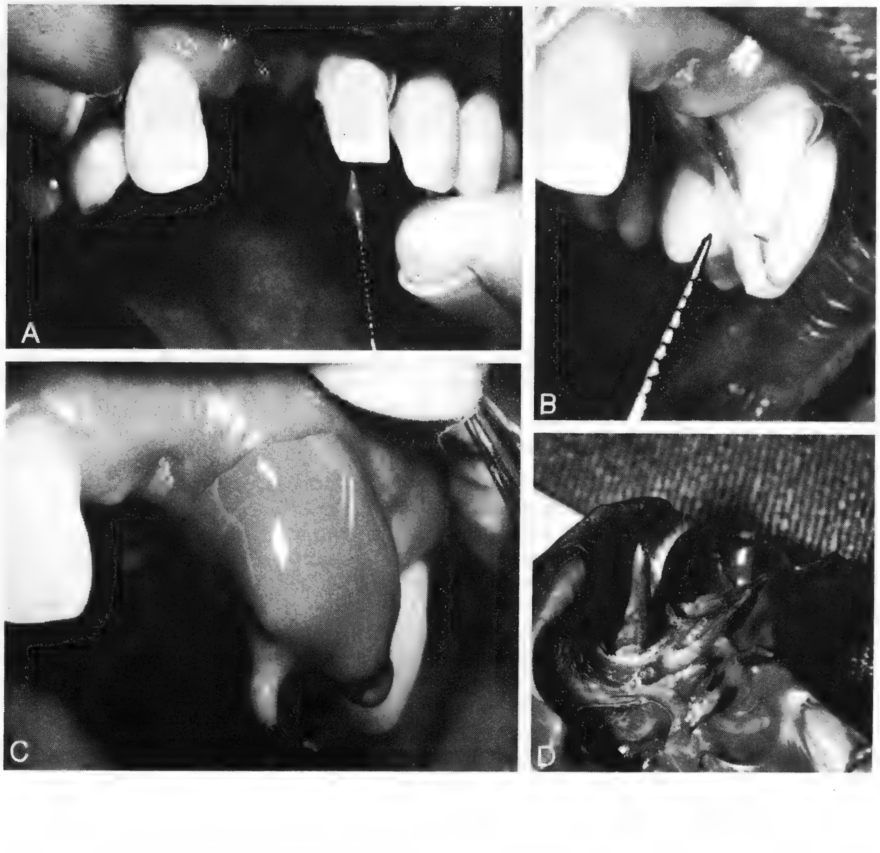


FIGURE 27–27 Post and Core Impression Technique

A, Post space being filled with rubber impression material using Lentulo Spiral instrument.
B, Inserting the safety pin into the post space. The pin has been bent on the coronal end, notched, and coated with adhesive.
C, Impression material covering preparations.
D, Polysulfide impression for post and core.

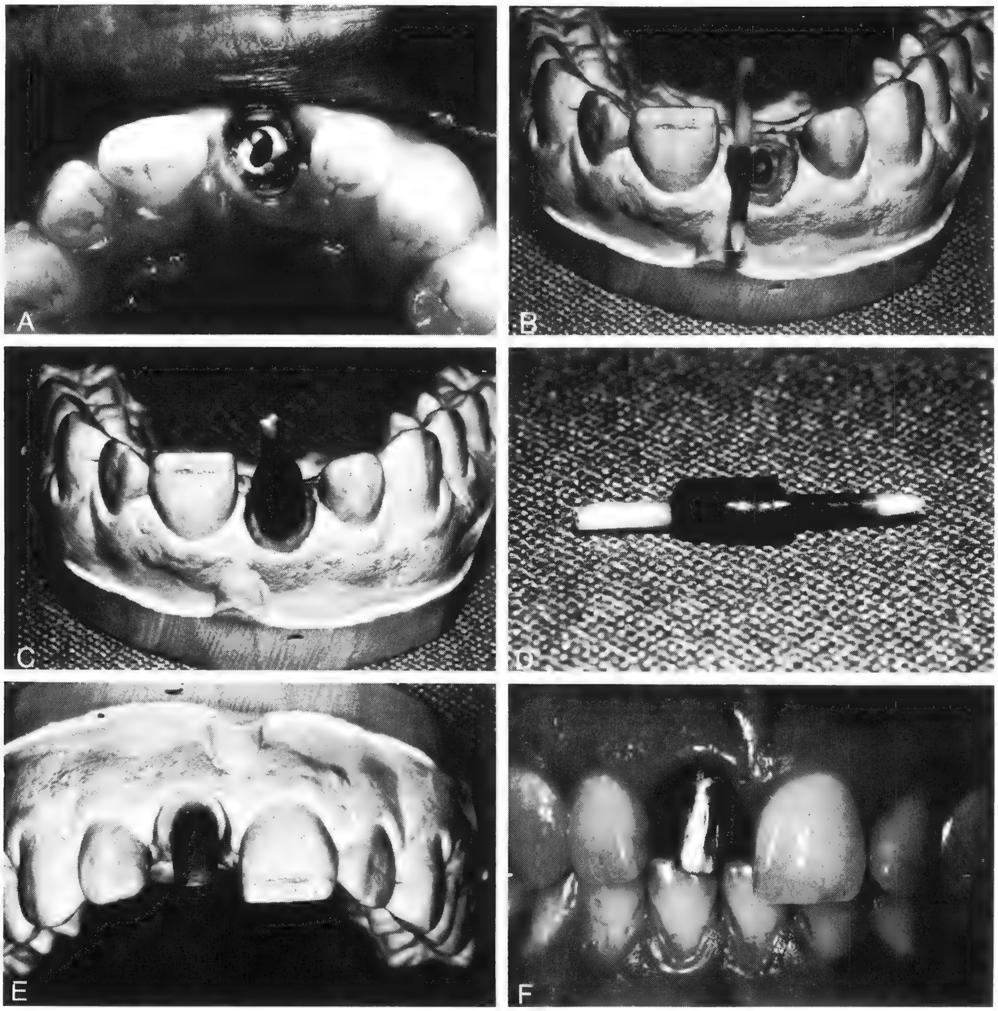


FIGURE 27–28 Indirect Post and Core Fabrication

A, Badly discolored tooth prepared for post and core.
B, Plastic post adapted to post space with wax.
C, Wax core formed.
D, Core pattern completed and removed.
E, Post and core on working cast.
F, Post and core cemented and preparation completed.

pattern is removed from the working cast (Fig. 27–28D), invested and cast (Fig. 27–28E), finished, and cemented (Fig. 27–28F).

Posts and Cores for Multirooted Teeth

As discussed previously, certain endodontically treated multirooted teeth can be restored without a post and core if sufficient coronal tooth structure remains. However, if the tooth is severely mutilated, a post and core is required, and adequate retention may only be achieved when more than one root canal is used.

Some root canals are aligned in the tooth so they can be prepared parallel to one another, and a one-piece casting can be fabricated. Another procedure is to use all the available length of one root canal and only part of the length in another canal (up to the point at which it becomes divergent) (Fig. 27–29). However, a multiple-piece post and core must be fabricated in some cases to utilize the retention of divergent root canals.

For multiple-piece posts and cores, the root canals are prepared independently of each other with no attempt being made to achieve parallelism. An impression is obtained of the prepared tooth by using supporting pins in the canals, and a cast is poured.

For two-piece posts and cores, the pattern for one of the canals is developed as usual, and a portion of the core is formed. The form of the partial core must be carved so it does not interfere with the path of insertion of the other prepared root canal. The female portion of a preformed attachment* is placed into the wax or a dovetail is carved into the pattern. The wax pattern is

*Mini-Rest, J. M. Ney Company, Bloomfield, CT 06002.

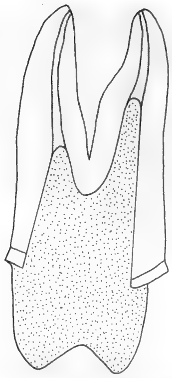


FIGURE 27–29 Cross section of one-piece casting using normal post length in one canal and short post extending into parallel portion of a second canal.

invested, cast, and seated on the working cast. A wax pattern is developed for the other root canal, and the male portion of a preformed attachment is inserted into the casting. The remainder of the core form is then established. With a custom-carved dovetail design, wax is simply made to flow into the dovetail of the casting as the core is formed. The wax pattern is invested, and the second casting is made. The second casting mechanically locks into the first casting to produce a stable well-retained post and core when the two castings are cemented in the tooth (Fig. 27–30). When necessary, three-piece post and cores can also be fabricated by the same procedure.

An alternative interlocking design for multirooted teeth involves the use of a cast post that fits one canal and an integral core that encompasses preformed pins, which fit into other divergent canals (Fig. 27–31A). A pattern is developed for one of the root canals and the core by using wax. It is formed around the tapered metal pins that have been inserted into the other canals (Fig. 27–31B). The metal pins have been coated with a thin film of die lubricant. They must project through the occlusal aspect of the core so they can be grasped. The metal pins are removed from the die along their separate paths of insertion; this approach permits removal of the core and its post so it can be invested and cast (Fig. 27–31C,D). Because of strength requirements, the pattern should be invested in a phosphate-bonded investment. Care must be exercised to ensure that investment completely fills the holes in the pattern. The casting is seated on the prepared tooth, and the metal pins are inserted through the holes in the casting to form a multiple-piece interlocking post and core (Fig. 27–31E). The post and core is cemented, and the excess pin length is ground off after the cement has hardened (Fig. 27–31F).

Clinical Adjustment and Cementation

It may be necessary to leave a section of the sprue attached to certain posts and cores in order to serve as a handle for clinical try-in and removal. Post and core restorations must be carefully placed into the tooth during trial insertion, since resistance to full seating of the casting can cause tooth fracture as the casting binds and attempts to expand the tooth. The post and core should seat passively with little discernible movement or rotation when it is seated. If significant movement occurs, a new post and core must be made that has better adaptation. However, if resistance is encountered, it may be possible to locate and eliminate the interference. Indicating materials such as Liqua-Mark* can be placed on the casting so that areas that bind are accurately identified and reduced. No attempt should be made to force the casting into position.

*Liqua-Mark, The Wilkinson Company, Westlake Village, CA 91361.

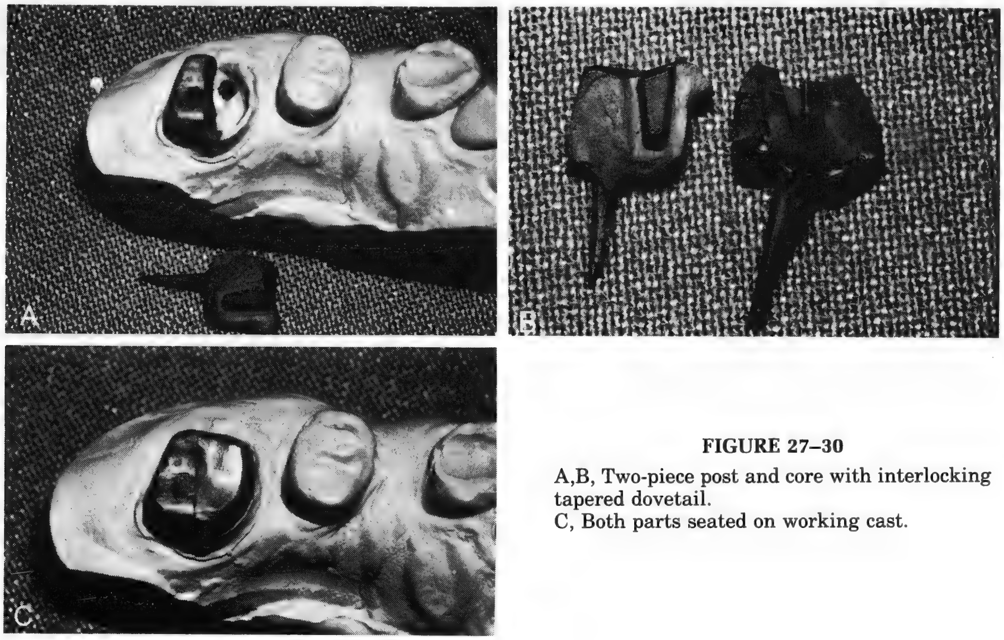


FIGURE 27–30

A,B, Two-piece post and core with interlocking tapered dovetail.
C, Both parts seated on working cast.

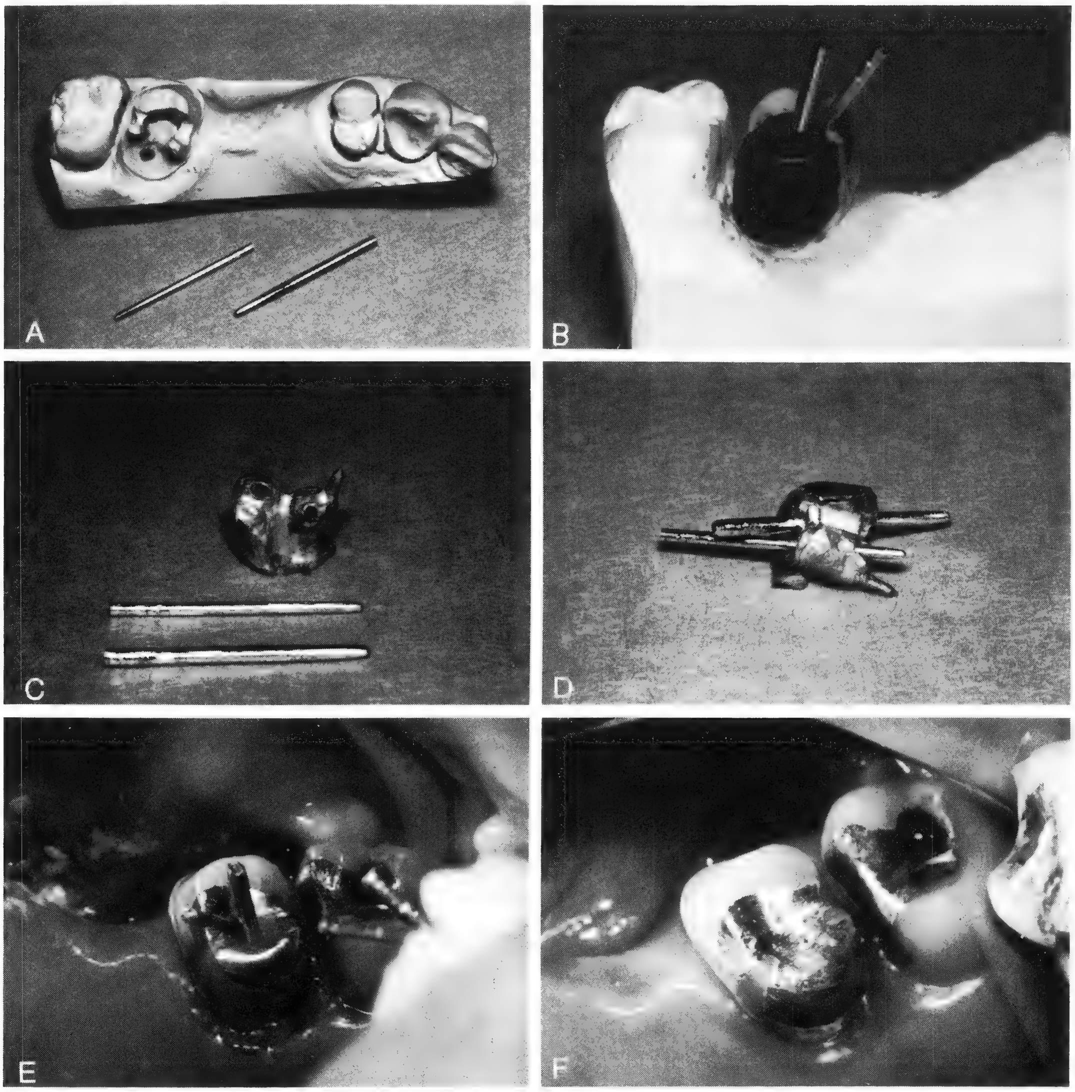


FIGURE 27–31 Three-Piece Post and Core

A, Working cast and precast metal pins for maxillary molar with three divergent canals.
B, Completed core pattern with two cast pins in place. Core form and mesiobuccal canal have been formed in wax.
C, Completed casting with metal pins.
D, Metal pins in place.
E, Trial insertion of core and metal pins.
F, Core cemented, pins shortened, and preparation completed.

When a passive accurate fit is verified, the occlusal clearance is checked to make sure that sufficient space remains for the final restoration. If this is not the case, the casting should be removed from the mouth and reduced. Intraoral grinding of an uncemented post and core produces detrimental forces that can split a tooth. As much as possible of the metal refinement should be done prior to cementation to minimize the vibratory forces subsequently applied to the casting.

The tooth is cleaned, isolated, and dried as usual. A cement should be used that provides adequate working time (such as zinc phosphate) and is not, or does not rapidly become, viscous. Some individuals advocate placing a small groove along the length of the post to facilitate the escape of cement.

Cement is placed into the canal with a Lentulo Spiral instrument. A thin layer is also applied to the casting, which is then seated into the tooth. A steady but modest force is applied with the fingers or a hand instrument until complete seating is achieved.

The cement must be allowed to completely harden before the tooth preparation is refined. A few extra minutes of setting time are indicated if the coronal tooth form is composed principally of the post and core.

The preparation is refined as usual with particular attention being paid to smoothing of the junction of the post and core with tooth structure.

28

Fixed Partial Denture Designs

Hypothetic examples of missing teeth are presented in this chapter along with a brief description of potential prosthesis designs. This information is intended to aid decisions regarding the number of abutment teeth required, retainer selection, and pontic design.

The required number of abutment teeth and the best type of retainer are determined only after a thorough evaluation of at least the following factors, which are discussed in detail in Chapter 2: crown length, crown form, degree of mutilation, root length and form, crown-root ratio, periodontal health, mobility, span length, axial alignment, arch form, occlusion, and pulpal health. Also, a composite evaluation of several of these items is often required before the most appropriate prosthesis design can be determined.

Esthetic requirements dictate that many pontics be metal-ceramic, so that when they are viewed facially they possess normal color and anatomic form. However, in nonvisible areas of the mouth, such as mandibular molars, a sanitary form of pontic that improves access with oral hygiene aids can be used. The sanitary form can be developed with an all-metal or a metal-ceramic design.

MAXILLARY DESIGNS

Replacement of a *single central incisor* (Fig. 28–1) is accomplished by using the approximating central and lateral incisors as abutments for a three-unit prosthesis with a metal-ceramic pontic.

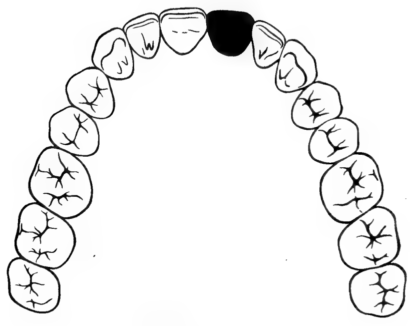


FIGURE 28–1

When the tooth condition and occlusal forces are favorable, the retainer design of first choice for both teeth is a pinledge. If greater retention and resistance form is required, partial veneer retainers can be used. When the incisors are very thin or highly translucent, pinledges or partial veneer crowns are not indicated both for mechanical and esthetic reasons. A thin tooth makes it extremely difficult, if not impossible, to achieve adequate reduction for metal thickness in a partial-coverage retainer and still develop adequate retention. Teeth that are highly translucent allow a partial-coverage casting to show through the tooth, which produces an esthetic problem.

When the proximoincisal angles are damaged, or if the teeth have large proximal restorations or large carious lesions, metal-ceramic retainers are indicated. Metal-ceramic retainers are also required when esthetic changes in color, form, or tooth position are desirable.

If the pulps are very large, such as those usually found in adolescents, resin-bonded prostheses may be advantageous. (These restorations are discussed in Chapter 31.)

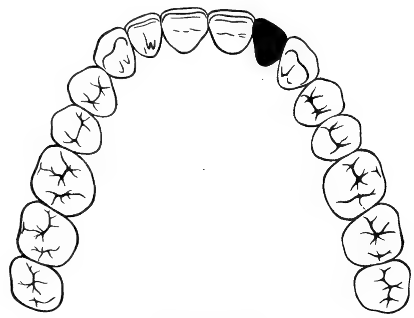


FIGURE 28–2

A missing *single lateral incisor* (Fig. 28–2) can be replaced by different prosthesis designs depending on arch stability and esthetic considerations. The most stable arrangement involves use of a three-unit prosthesis from the central incisor to the canine. The design of first choice includes a pinledge retainer on the incisor, a partial veneer crown on the canine, and a metal-

ceramic pontic. If the degree of mutilation of either abutment necessitates full coverage, a metal-ceramic restoration is indicated, in conjunction with a metal-ceramic pontic and the appropriate partial-coverage restoration on the other abutment tooth. When both abutments need full coverage, a total metal-ceramic prosthesis is indicated. However, a disadvantage of placing a metal-ceramic restoration on the central incisor relates to esthetics when the restoration does not exactly match the color of the adjacent central incisor. When this problem is anticipated from causes such as unique tooth color or a large pulp that does not permit adequate reduction of the central incisor, consideration should be given to other esthetically advantageous prosthesis designs.

It is possible to cantilever a metal-ceramic pontic from a partial veneer crown on the canine when crown form and tooth condition permit the use of partial coverage. Otherwise, a two-unit metal-ceramic prosthesis is recommended. Cantilevering requires a stable arch form. Rotated, overlapped, or malpositioned teeth must not be present. Many prostheses of this design have been successfully used, yet others have failed. A certain risk is present with a cantilever design, since the potential for failure cannot always be accurately predicted. Facial forces applied to the pontic can cause some canines to rotate, allowing the pontic to slip out of proximal contact with the central incisor, which results in collapse of the arch. However, this is one of the better locations in which to take the risk, and the esthetic advantages acquired by not involving the central incisor may justify the risk. A rest can be extended from the pontic to the lingual surface of the central incisor to improve stability. The rest can even be dovetailed into an inlay in the central incisor in order to attain even better stability.

When a two-unit cantilever is considered too risky, and esthetic or mechanical difficulties prevent use of the central incisor, it is also possible to cantilever the lateral incisor from the canine and first premolar, which have been splinted.

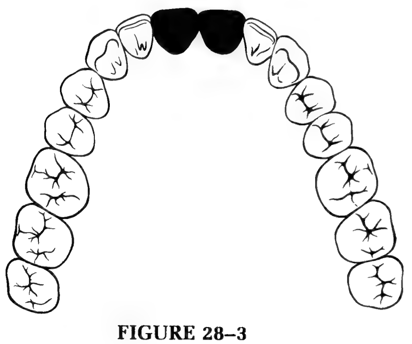


FIGURE 28–3

A fixed partial denture replacing *both central incisors* (Fig. 28–3) can be made by using only the lateral incisors as abutments, provided that their root form and length are good and that bone support is satisfactory. Pinledge or partial veneer retainers can be used when the lever arm is short and the occlusal forces are minimal. Otherwise, metal-ceramic retainers are indicated. Some lateral incisors do not provide adequate prosthesis support because of their root form and length, but they can be used successfully when they are splinted to the canines. The presence of reduced bone support on the lateral incisors also indicates the use of both the lateral incisors and canines as multiple abutments. Metal-ceramic retainers are generally indicated when multiple abutment teeth are used.

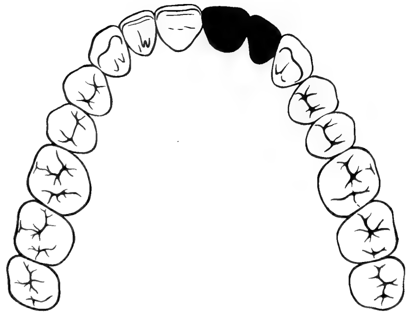


FIGURE 28–4

Replacing the *approximating central and lateral incisors* (Fig. 28–4) ordinarily involves only two abutment teeth, namely, the remaining central incisor and the canine approximating the space. Partial-coverage retainers can be used successfully when crown form, alignment, and tooth condition permit.

If there is reduced bone support around the central incisor, the lateral incisor should be included. While a lone lateral incisor is not an exceptionally strong tooth, when it is splinted to the central incisor the resulting two-rooted multiple abutment adequately resists rotation and displacement. When the lateral incisor is poorly aligned with the path of insertion and three abutments are needed, the prosthesis can be attached to the central incisor, canine, and first premolar.

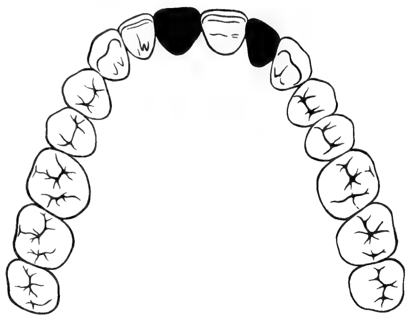


FIGURE 28–5

Designing a prosthesis to replace the *central incisor on one side of the midline and the lateral incisor in the adjacent quadrant* (Fig. 28–5) is an entirely different matter from the one just discussed. Because of their locations, the canine and central incisor do not provide support comparable with that derived from the two abutments in the preceding design. The proximity of the central incisor to the canine would possibly allow a cantilevered central incisor pontic to exert excessive

leverage on the central incisor abutment; consequently, the remaining lateral incisor should be used as a terminal abutment. The option between pinledge, partial veneer, or metal-ceramic retainers is decided by crown form, tooth condition, long-axis relationship, lever arm, and occlusal forces.

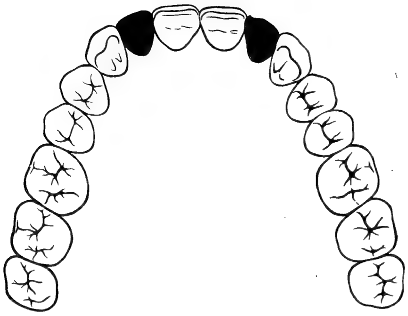


FIGURE 28–6

In a case in which *both lateral incisors* (Fig. 28–6) are missing, two three-unit prostheses should be constructed rather than a single one of six units. A continuous six-unit prosthesis would only be advantageous when there has been considerable bone loss around the central incisors, and this design would indicate the use of metal-ceramic retainers. As discussed previously, conditions could also indicate the bilateral use of lateral incisor pontics cantilevered from canine retainers or from splinted canines and first premolars.

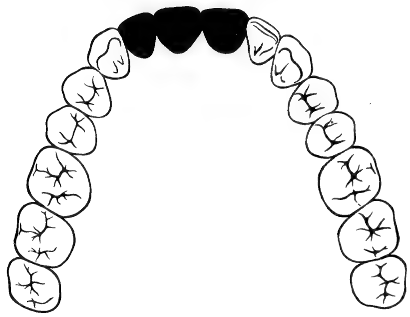


FIGURE 28–7

When the *two central incisors and one lateral incisor* (Fig. 28–7) have been lost, a six-unit prosthesis extending from canine to canine with three abutment teeth is generally indicated. However, if the lateral incisor has excellent root form, length, and bone support, it can be used as the lone abutment on one side of a five-unit prosthesis. Occasionally, the lateral incisor has poor root form and length coupled with reduced bone support. Its removal with fabrication of a six-unit prosthesis from canine to canine is the best solution. A metal-ceramic prosthesis is generally indicated, but occasionally partial veneer crowns can be designed and executed to adequately resist occlusal forces.

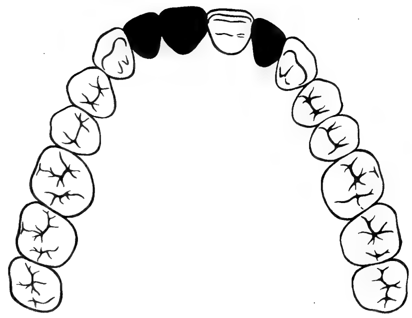


FIGURE 28–8

Replacement of *one central and two lateral incisors* (Fig. 28–8) is not a difficult task unless the remaining central incisor has drifted out of position. If there is harmony in the long-axis relationship, this bridge can be constructed by using the central incisor and both canines as abutments. With good tooth form and alignment, partial veneer retainers can be successful, but more frequently metal-ceramic retainers are required.

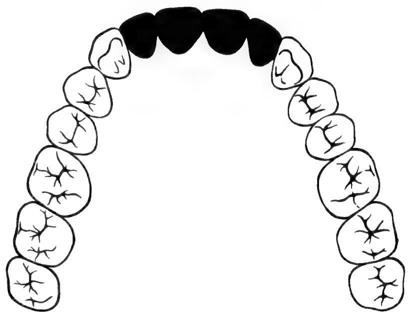


FIGURE 28–9

To replace *four incisors* (Fig. 28–9), generally a six-unit prosthesis utilizing metal-ceramic retainers is indicated. Occasionally, the alignment, crown form, and length of the canines allow the successful use of partial veneer retainers. The length of the lever arm anterior to the canines has a bearing on the number of abutment teeth used. A long lever arm may necessitate bilateral splinting of the canines and first premolars and fabrication of an eight-unit prosthesis. Reduced bone support around the canines can also indicate use of the first premolars to aid in prosthesis support. The presence of considerable bone loss, or malalignment of the canines, can also require the use of a removable prosthesis. Also, a removable partial denture can provide better esthetics when there is considerable alveolar ridge resorption or a need to leave diastemas or create tooth arrangements in which the artificial teeth are malpositioned relative to each other.

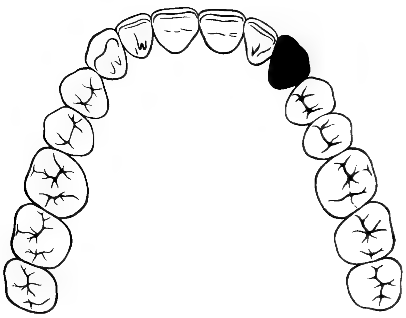


FIGURE 28–10

Replacement of a *single canine* (Fig. 28–10) can often be managed by using the lateral incisor and first premolar as abutments. However, this requires careful management of the occlusion so as not to place excessive forces on the pontic during eccentric mandibular movements. Partial veneer or metal-ceramic retainers have both been used successfully, depending on tooth condition. Multiple abutments are indicated in the presence of reduced bone support, a longer than normal lever arm, or heavy eccentric occlusal forces, which are particularly concentrated in the canine area. It may be necessary to utilize both premolars as abutments and, on rare occasions, the central incisor as well.

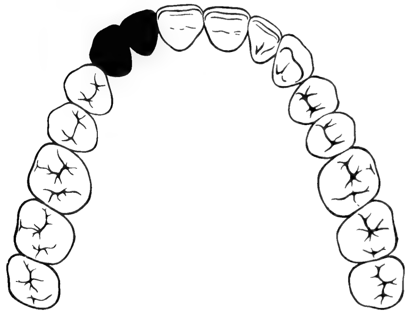


FIGURE 28–11

The absence of a *canine and approximating lateral incisor* (Fig. 28–11) is rare. This is fortunate, since resistance to the lever arm in such situations cannot be readily obtained. No less than three abutment teeth should be used, preferably the two premolars and one central incisor. When the crown-root ratio, arch contour, or occlusion is abnormal, the second central incisor should be used. Metal-ceramic retainers are generally required, although partial veneer crowns can be used on the premolars when they possess good crown length and form and little mutilation.

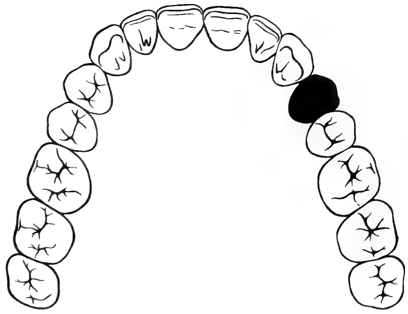


FIGURE 28–12

Replacement of the *first premolar* (Fig. 28–12) routinely can be managed by using the canine and second premolar as abutments. Partial veneer crowns are the retainers of first choice, along with a metal-ceramic pontic, unless the tooth condition warrants metal-ceramic retainers.

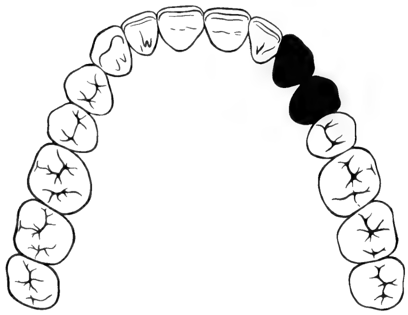


FIGURE 28–13

In replacing the *canine and first premolar* (Fig. 28–13), generally the first molar, second premolar, lateral incisor, and central incisor are used as abutments. Adequate resistance and retention form usually require full coverage, but partial coverage can sometimes be used posteriorly. With good bone support, tooth alignment, and root form, it may be possible to use only the second premolar as the terminal abutment.

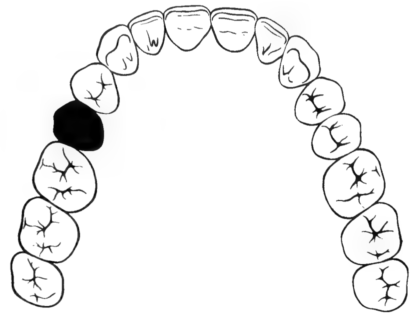


FIGURE 28–14

A missing *second premolar* (Fig. 28–14) is best replaced with a metal-ceramic pontic connected to partial veneer crown retainers on the first premolar and first molar.

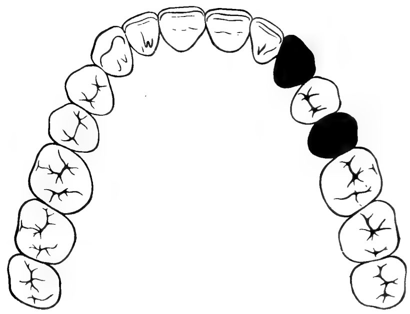


FIGURE 28–15

When the *canine and second premolar* (Fig. 28–15) are missing, the occlusal forces present and the bone support around the first premolar and lateral incisor must be critically examined. If normal occlusion and crown-root ratio are present, three abutments (first molar, first premolar, and lateral incisor) are sufficient. In the presence of heavy lateral occlusal forces or reduced bone support, the central incisor should be added anteriorly. Full-coverage retainers are generally indicated.

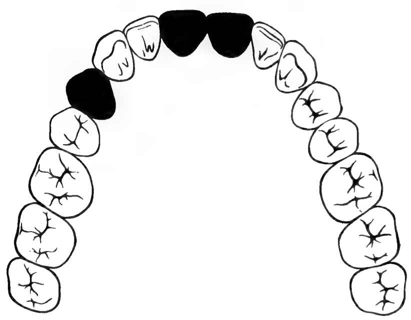


FIGURE 28–16

Replacement of *both central incisors and one first premolar* (Fig. 28–16) can be handled with two separate prostheses or with one. Whenever possible, two smaller prostheses are preferable to one longer restoration. If a future problem develops around one abutment tooth, this is more catastrophic when one large prosthesis must be remade.

If the lateral incisors allow placement of a four-unit incisor prosthesis, the first premolar can be replaced with a traditional three-unit restoration. However, in the absence of adequate lateral incisors, an eight-unit prosthesis is indicated with full-coverage retainers on the canines, lateral incisors, and second premolar.

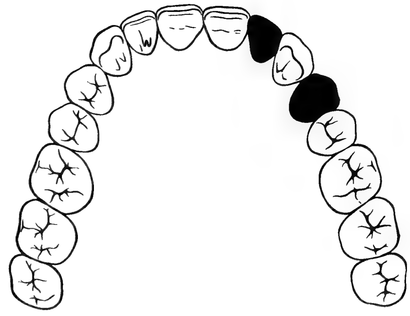


FIGURE 28–17

When the *lateral incisor and first premolar* (Fig. 28–17) are missing, usually the canine and second premolar can support a four-unit prosthesis with a cantilevered lateral incisor. Only the presence of heavy lateral occlusal forces or reduced bone support would make it necessary to use the central incisor as an anterior abutment. Whenever possible, partial veneer crown retainers should be used.

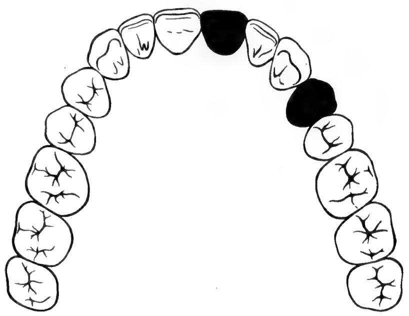


FIGURE 28–18

Replacement of the *first premolar and central incisor in the same quadrant* (Fig. 28–18) is best accomplished with two three-unit prostheses.

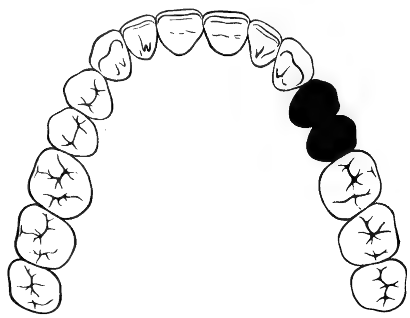


FIGURE 28–19

When *both the first and second premolars* (Fig. 28–19) are missing, a successful four-unit prosthesis can be fabricated with full coverage on the first molar and partial coverage on the canine. If it is questionable whether adequate retention can be developed on the canine, a metal-ceramic retainer is indicated.

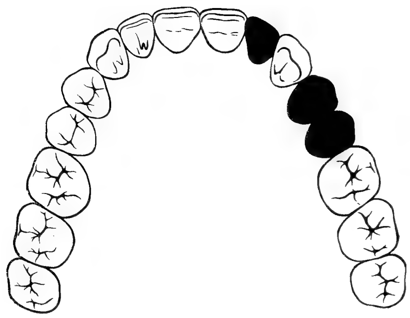


FIGURE 28–20

Loss of *both premolars and a lateral incisor* (Fig. 28–20) can be handled with a five-unit prosthesis cantilevering the lateral incisor from the canine abutment with the first molar serving as the only other abutment tooth. Full coverage is indicated on both abutment teeth. The lack of normal periodontal support around the canine or heavy lateral chewing forces, or both, indicate the need to include the central incisor in a six-unit full-coverage prosthesis.

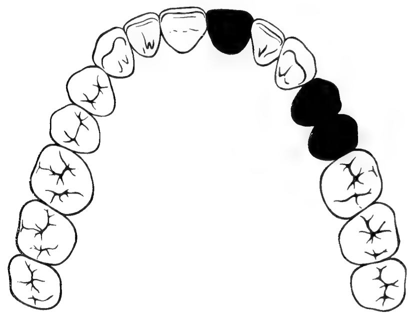


FIGURE 28–21

Two prostheses should be constructed to replace *two premolars and the central incisor* (Fig. 28–21) in the same quadrant.

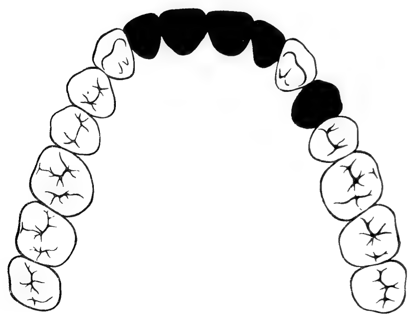


FIGURE 28–22

A prosthesis that replaces the *four incisors and a first premolar* (Fig. 28–22) would generally consist of eight units using full coverage on the canines and second premolar abutment teeth. However, the loss of these five teeth may leave reduced bone support around the abutment teeth, which necessitates a ten-unit bridge using the first premolar and canine as splinted abutments on one end of the prosthesis, an intermediary canine abutment, and the second premolar and first molar as splinted abutments on the other end. Significant bone loss can also mandate a removable prosthesis.

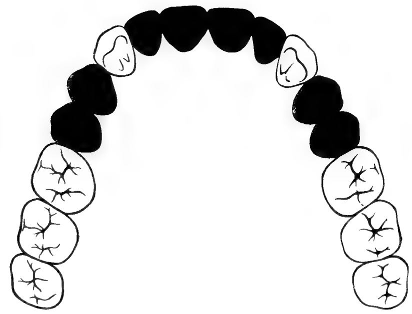


FIGURE 28–23

Replacement of the *four incisors and the four premolars* (Fig. 28–23) usually requires a removable partial denture, since the bone support and ridge form are often compromised. A twelve-unit fixed prosthesis could be considered if optimal bone support is present and if retentive preparations can be developed. However, the patient must have a complete understanding of the advantages and disadvantages of the two alternative methods of tooth replacement. Only when an extreme desire is expressed to avoid a removable prosthesis should a fixed prosthesis of this length be used. The patient must understand the consequences of prosthesis failure.

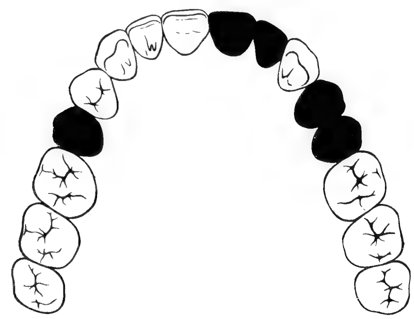


FIGURE 28–24

When the *two premolars and the central and lateral incisor in one quadrant* (Fig. 28–24) are missing, a fixed prosthesis is indicated using the central incisor, canine, and first molar as abutments. If the central incisor or canine is weakened periodontally, the prosthesis can be extended to include the lateral incisor. Full-coverage retainers are necessary.

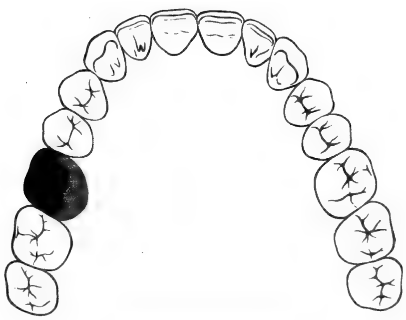


FIGURE 28–25

A missing *first molar* (Fig. 28–25) is best replaced with a partial veneer crown on the second premolar abutment tooth and a full veneer crown on the second molar abutment tooth.

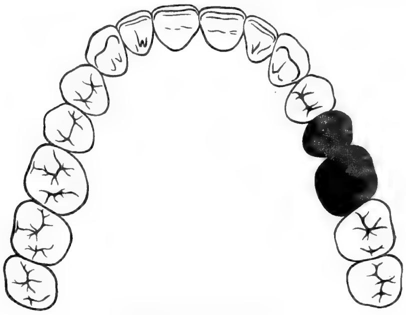


FIGURE 28–26

When the *approximating second premolar and first molar* (Fig. 28–26) are lost, a four-unit prosthesis is indicated that uses a full veneer crown on the molar. Available crown length for retention and occlusal forces determine whether the premolar abutment retainer requires partial or full coverage. Inclusion of the canine and fabrication of a five-unit restoration are indicated when the first premolar has marginal root form or bone support.

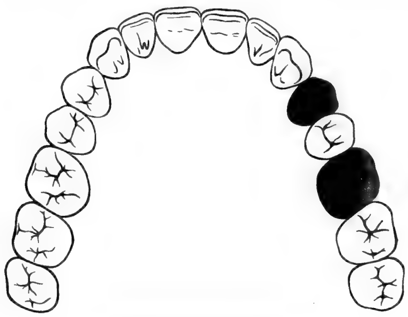


FIGURE 28–27

Replacing the *first premolar and first molar on the same side* (Fig. 28–27) is usually handled by placing a five-unit prosthesis with the canine, second premolar, and second molar as abutments. Partial veneer crowns can be used on the canine and premolar if optimal crown length is available for retention. It is also possible to fabricate a four-unit bridge with the first premolar cantilevered from the second premolar retainer when the second premolar has good bone support, root length, and root form. This design generally requires a full-coverage retainer on the second premolar.

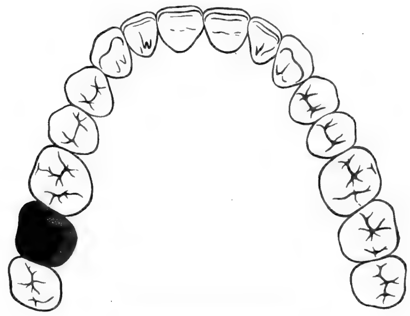


FIGURE 28–28

Occasionally the *second molar* (Fig. 28–28) is missing, and the third molar is present. If the third molar has good root form and alignment with the first molar and is accessible, a three-unit prosthesis can be fabricated. Generally, full-coverage is indicated on both abutments, although adequate retention can be achieved on some long first molars with a partial veneer crown.

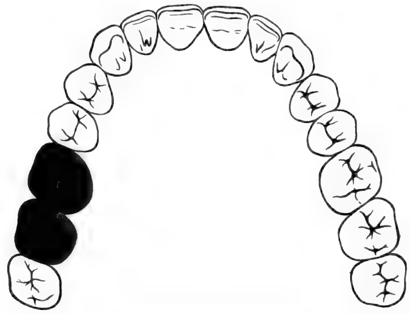


FIGURE 28–29

It is also possible for the *approximating first and second molars* (Fig. 28–29) to be missing while the third molar remains in position. A four-unit fixed prosthesis employing full coverage can only be made when the third molar crown form and its alignment with the second premolar allow a retentive preparation to be developed. Also, the root length and form should be comparable with those of a normally developed second molar, and the tooth must be accessible for preparation procedures. When these criteria cannot be met, a removable prosthesis is indicated.

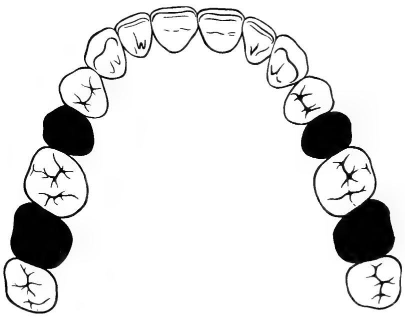


FIGURE 28–30

When a *second premolar and second molar* (Fig. 28–30) are missing, a five-unit full-coverage prosthesis can be made only if the third molar is present and if it qualifies as a suitable abutment. Otherwise, a three-unit bridge from the first premolar to the first molar is indicated. Occasionally a four-unit prosthesis that cantilevers a smaller than normal second molar pontic off the first molar abutment retainer can be fabricated if this is necessary to achieve occlusal contact with a mandibular second molar and thereby maintain its arch position.

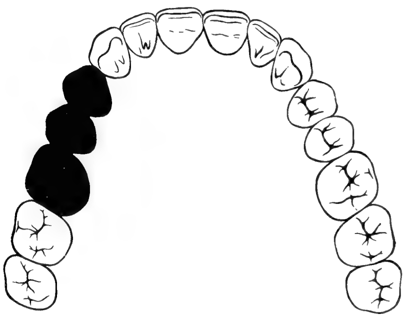


FIGURE 28–31

Replacement of the *approximating first molar, second premolar, and first premolar* (Fig. 28–31) usually requires a removable prosthesis. Occasionally, the canine and second molar have well-developed crowns and roots, excellent bone support is present, the occlusion is favorable, and the tooth alignment allows fabrication of a five-unit fixed prosthesis utilizing full-coverage retainers. Although the span length is long, the lever arm is minimal, and the fixed prosthesis can serve for a reasonable time.

MANDIBULAR DESIGNS

Replacement of a *single central incisor* (Fig. 28–32) rarely requires more than a three-unit fixed prosthesis. The abutment retainers on the central and lateral incisors can be metal-ceramic or partial-coverage. Neither preparation is easy to accomplish ideally on such small teeth, but some of the more rewarding esthetic restorations have been developed by using lingual-approach pinledge retainers and a metal-ceramic pontic. In the presence of very large pulps, as in an adolescent, resin-bonded prostheses can yield a pleasing esthetic result. (These restorations are discussed in Chapter 31.)

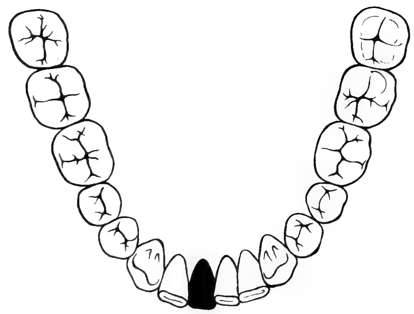


FIGURE 28–32

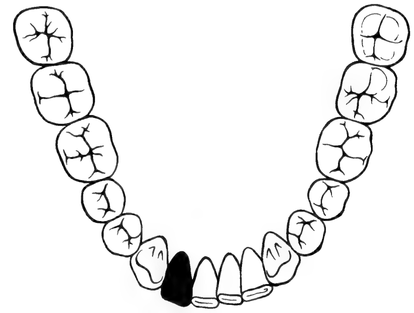


FIGURE 28–33

A single *missing lateral incisor* (Fig. 28–33) is usually replaced in the same manner as the central incisor. However, a variation sometimes useful in avoiding the difficult preparation of a central incisor involves a two- or three-unit cantilever in which the lateral incisor is attached to the canine or to the splinted canine and first premolar.

When a *single canine* is missing, a three-unit fixed prosthesis is indicated that utilizes partial or full coverage, depending on tooth condition. The prosthesis can be made to extend from the first premolar to the lateral incisor, or both premolars can be splinted with a cantilevered canine pontic if it is esthetically or biologically advantageous to avoid preparation of the lateral incisor.

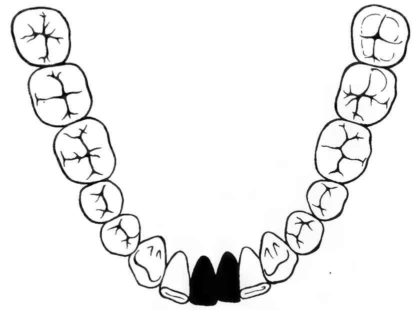


FIGURE 28–34

If *both central incisors* (Fig. 28–34) have been lost and there is reasonable bone support around the lateral incisors, a four-unit metal-ceramic prosthesis should be used.

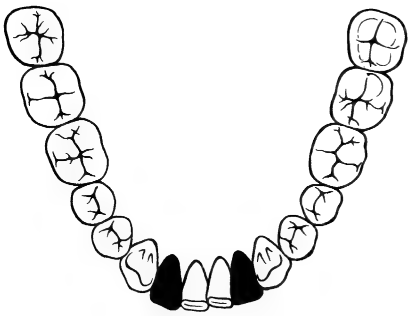


FIGURE 28–35

Replacement of *both lateral incisors* (Fig. 28–35) indicates the use of two three-unit prostheses extending from the canine to the central incisor. When the central incisors are mobile and have suffered some bone loss, designs include either a six-unit prosthesis or two three-unit prostheses in which the lateral incisor pontic is cantilevered from the canine and first premolar, which have been splinted. If considerable bone loss has occurred around the central incisors, it may be advantageous to remove these teeth and to fabricate a six-unit prosthesis from canine to canine.

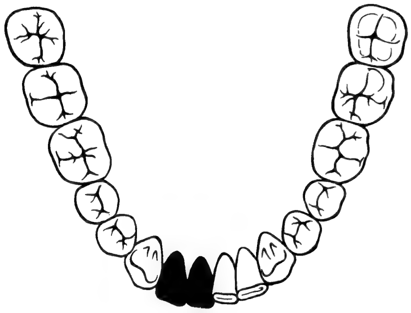


FIGURE 28–36

A fixed prosthesis replacing the *central and lateral incisor* (Fig. 28–36) in one quadrant generally requires metal-ceramic abutment retainers on the canine and the central incisor. A five-unit restoration including the lateral incisor is required when marginal stability is exhibited by the central incisor.

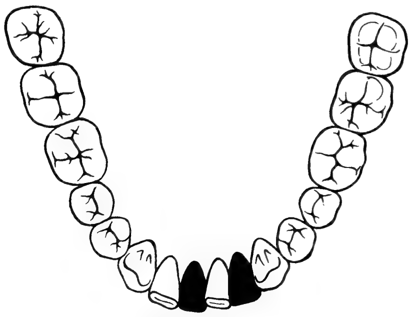


FIGURE 28–37

Loss of a *central incisor on one side of the midline and a lateral incisor on the other* (Fig. 28–37) is handled with a five-unit metal-ceramic prosthesis from the lateral incisor to the opposite canine.

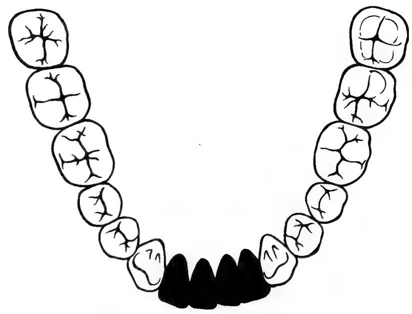


FIGURE 28–38

Occasionally *three missing incisors* can be replaced with a five-unit prosthesis, but this design requires good crown form, root form, and root length. More often, a six-unit full-coverage prosthesis extending from canine to canine would be utilized. The remaining incisor is an expendable tooth, and its extraction could be considered to make tooth preparation and prosthesis design less complicated (Fig. 28–38).

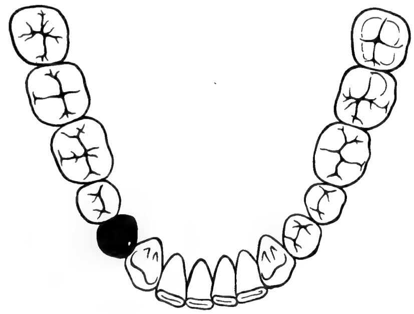


FIGURE 28–39

A missing *first premolar* (Fig. 28–39) is replaced by using a three-unit prosthesis with partial veneer crowns on the canine and the second premolar. A metal-ceramic retainer may be required on certain mandibular canines for esthetic reasons or because the tooth has no cingulum and very short proximal walls. This situation necessitates full coverage to achieve adequate retention, although the tooth condition would not otherwise indicate full coverage.

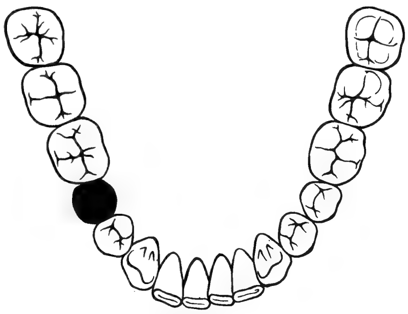


FIGURE 28–40

A three-unit fixed prosthesis with partial veneer crowns on the first premolar and first molar is generally used to replace a *second premolar* (Fig. 28–40). Certain mandibular first premolars resemble canines in form,

having short proximal walls and a poorly developed lingual cusp, and necessitate full coverage. Esthetics may also dictate the use of a metal-ceramic restoration. The cervical aspect of many second premolar crowns is not visible during talking or smiling, and a sanitary form of pontic can be used to facilitate oral hygiene procedures.

FIGURE 28–41

The *first molar* (Fig. 28–41) is replaced with a three-unit prosthesis in which a partial veneer retainer is used on the second premolar and a full veneer crown on the second molar. Very few first molar replacements require anything other than a sanitary form of pontic.

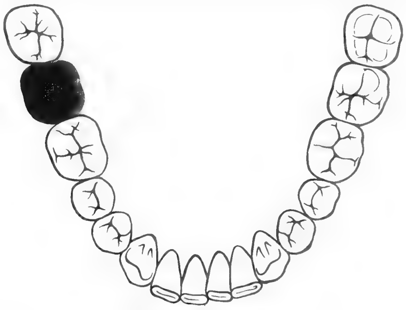


FIGURE 28–42

When the third and first molars can be used in the replacement of the *second molar* (Fig. 28–42), the retainers should be full veneer crowns with a sanitary form of pontic.

FIGURE 28–43

When *both premolars* (Fig. 28–43) are missing, a four-unit prosthesis with full-coverage retainers is indicated. Likewise, a four-unit prosthesis utilizing full coverage is the treatment of choice when the *second premolar and first molar* (Fig. 28–44) are missing.

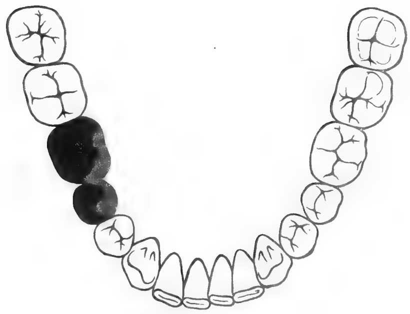


FIGURE 28–44

Replacement of the *first premolar and first molar* (Fig. 28–45) can be handled with a four- or five-unit prosthesis, depending on the root form, root length, and bone support of the second premolar. A four-unit prosthesis with a cantilevered first premolar can be used in the presence of good root form, root length, and bone support.

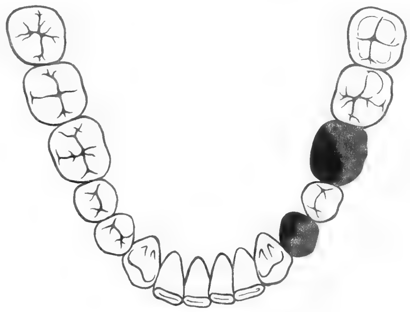


FIGURE 28–45

Otherwise, a five-unit bridge using the canine as the anterior abutment tooth is desirable. Full coverage is generally indicated.

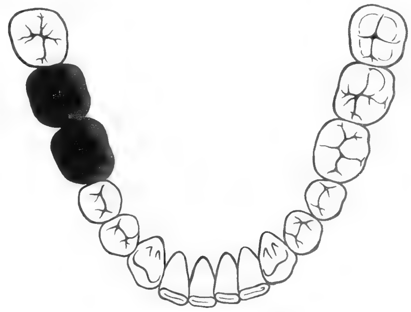


FIGURE 28–46

Occasionally a third molar is in good alignment, has good crown form, and well-developed roots, which allow it to serve as an abutment for a four-unit bridge replacing the *first and second molars* (Fig. 28–46). In the presence of poor alignment and root form, a removable prosthesis should be used.

FIGURE 28–47

When *both premolars and the first molar* (Fig. 28–47) are missing, a removable partial denture is usually the treatment of first choice, although five-unit fixed prostheses have been fabricated when ideal crown and root form and length, axial alignment, and bone support are present.

SUMMARY

While many clinical situations can occur that have not been discussed in this chapter, it is hoped that the principles set forth can be applied to the design of mechanically sound and esthetically pleasing prostheses for any single edentulous area or combination of areas.

29

Clinical Failure

It is important to be aware of obvious and subtle indications of prosthesis failure and to have a working knowledge of the procedures that are necessary to remedy the situation.

It is natural that dramatic mechanical failures, such as fracture, attract attention, but it must be remembered that failures can also be esthetic or biologic in nature. Some failures are the result of poor patient care, while others occur as a result of defective design or inadequate execution of the clinical or laboratory procedures. Other failures are considered "normal" because changes in the oral environment that are not related to the prosthesis necessitate its removal and reconstruction. Also, a restoration may simply wear out. After all, prostheses cannot routinely be expected to last a lifetime. As a matter of fact, when all of the formidable problems encountered in the oral environment are considered, it is amazing that restorations last as long as they do.

BIOLOGIC FAILURES

CARIES

Caries is one of the most common biologic failures, and early detection is possible mainly through comprehensive probing of the margins of the prosthesis and tooth surfaces with a sharp explorer. Radiographs are also helpful, particularly interproximally. Lesions can occur on an abutment tooth at the restoration margin (Fig. 29–1) or at a location dissociated from the prosthesis. Conventional operative dentistry procedures can generally be used to restore small carious lesions without the need to fabricate a new prosthesis (Fig. 29–2).

Gold foil is the filling material of first choice for restoring marginal caries. However, access to the prepared area can restrict the use of foil. Amalgam is the best alternative material because of its ability to produce a long-term marginal seal. It can also be manipulated into areas of limited access and subsequently carved to achieve a relatively smooth surface from which plaque can be cleansed (Fig. 29–3). Resin materials are less desirable, but marginal lesions in visible locations may dictate the use of such a tooth-colored restorative material. Glass ionomer cement may also be considered in such cases.

Carious lesions in certain locations, such as proximal surfaces, may require removal of the prosthesis (this procedure is discussed later in this chapter) to obtain access to the caries. If the lesion is sufficiently small, the tooth preparation can be extended to eliminate the caries, and a new prosthesis can be fabricated. When a larger lesion is present, an amalgam restoration is often required after removal of the restoration and excavation of caries. The abutment preparation is extended to cover the filling, and a new restoration is fabricated. Extensive lesions may encroach on the pulp, making endodontic treatment necessary (Fig. 29–4), or the tooth may be so

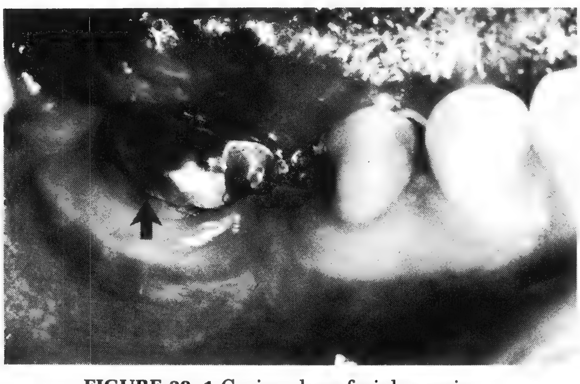


FIGURE 29–1 Caries along facial margin.

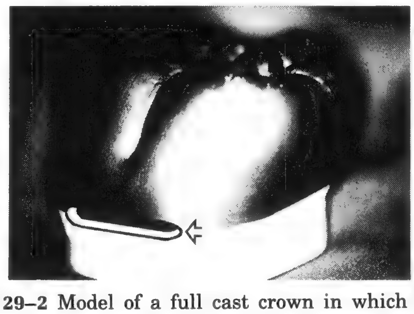


FIGURE 29–2 Model of a full cast crown in which marginal caries have been removed using a slotlike preparation following the margin. The preparation possesses internal undercuts to provide retention for the restorative material. (Courtesy of T.J. Carlson.)

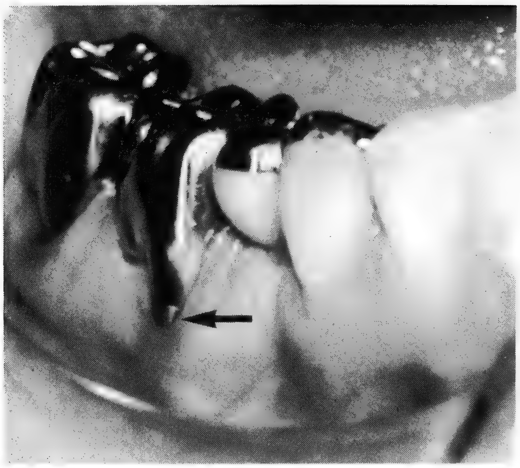


FIGURE 29–3 Amalgam restoration placed at the site of a small mesiofacial carious lesion.

FIGURE 29–4 Extensive carious lesion producing pulp exposure in the canine.

destroyed by caries that it cannot be restored and must be extracted (Fig. 29–5).

Marginal carious lesions generally begin at the surface and progress inward. They can also occur internally and not be readily discernible on the external surface until extensive destruction has occurred, which eventually progresses to the margin. This problem can be the result of incomplete removal of caries during a previous treatment or of a loose retainer casting that allows gross leakage to occur.

Meticulous oral hygiene must be a routine procedure for patients with a high caries index and particularly for those who have a past history of developing carious lesions around restorations. Other preventive measures should include the use of fluoride-containing dentifrices, home mouth rinses containing fluoride, and professionally applied topical fluoride.

Pulp Degeneration

Postinsertion pulpal sensitivity on abutment teeth that does not subside with time, intense pain, or periapical abnormalities that are detected radiographically often indicate the need for endodontic intervention. Access to the pulp requires preparation of a hole in the prosthesis through which the necessary treatment is completed. Frequently, the perforation can be restored with gold foil (Fig. 29–6), amalgam (Fig. 29–7), or a cast metal inlay (Fig. 29–8) without compromising the prosthesis. Occasionally other treatment is necessary.

The retainer casting may come loose during preparation of the access opening or the porcelain may fracture, necessitating remaking of the prosthesis.

During endodontic treatment, an assessment should be made of the quantity and quality of tooth structure remaining for support and retention of the restoration. When little sound tooth structure remains, it may be necessary to place a post and core and to fabricate a new restoration.

Periodontal Breakdown

Periodontal disease can produce extensive bone loss that in time results in the loss of abutment teeth and attached prostheses. Less severe breakdown can be treated without fear of loss of the teeth, but treatment often involves surgery, which may produce an unacceptable relationship between the prosthesis and the soft tissue.

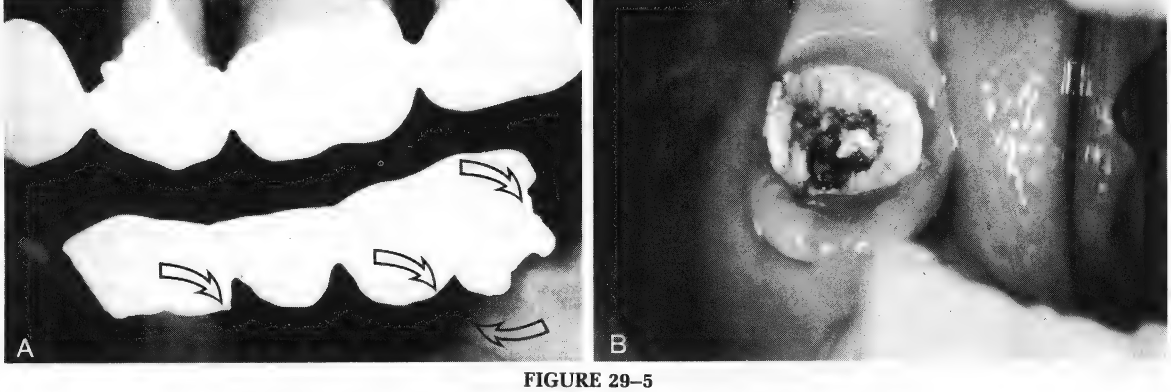


FIGURE 29–5

A, Arrows indicate radiographic evidence of extensive caries under the prosthesis.
B, Removal of prosthesis reveals unrestorable remaining tooth structure, requiring extraction.

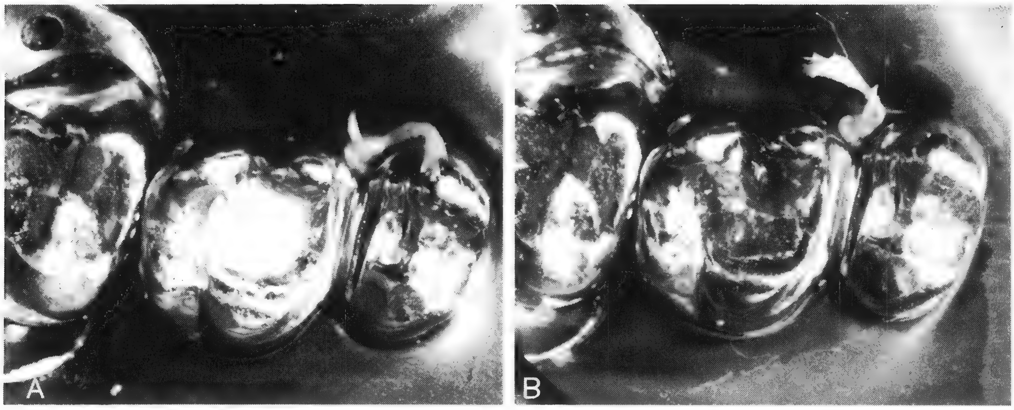


FIGURE 29–6
A, Temporary cement in endodontic access opening.
B, Gold foil restoration used to repair casting perforation. (Courtesy of M.R. Lund.)

In some situations, the disease process may be present in both restored and nonrestored areas of the mouth but with no relationship to the prosthesis. It also can be localized around the prosthesis, as a result of inadequate instruction in prosthesis hygiene, poor implementation of proper hygiene procedures, or a restoration that hinders good oral hygiene. Aspects of a prosthesis that interfere with effective plaque removal include poor marginal adaptation and overcontouring of the axial surfaces of the retainers, excessively large connectors that restrict the cervical embrasure space (Fig. 29–9), a pontic that contacts too large an area on the edentulous ridge (Fig. 29–10), or a prosthesis with rough surfaces, which promote plaque accumulation.

A prosthesis that hinders effective plaque removal must be recontoured or remade to correct such defects.

Occlusal Problems

Interfering centric or eccentric occlusal contacts can cause excessive tooth mobility (Fig. 29–11). If this is detected early, the interferences can be eliminated by occlusal adjustment without permanent damage. However, traumatic occlusion on teeth previously weakened by periodontal disease or the long-term presence of occlusal interferences on teeth with normal bone support can lead to mobility, which cannot be reduced or eliminated through adjustment of the interfering areas. The prosthesis may have to be removed and the teeth bilaterally braced with a removable partial denture. Occasionally, the combination of excessive mobility and reduced bone support require extraction of abutment teeth. The presence of interfering occlusal contacts can also cause irreversible pulpal damage requiring endodontic treatment.

FIGURE 29–7 Amalgam placed in endodontic access opening of maxillary molar.

Neuromuscular discomfort related to improper occlusion can result in prosthesis failure, since occlusal adjustments that are required to allow the mandible to be properly positioned may cause perforation of the prosthesis or make the restoration esthetically unacceptable.

Tooth Perforation

Pinholes or pins used in conjunction with pin-retained restorations can be improperly located and may perforate the tooth laterally. If the perforation is located occlusal to the periodontal ligament, it is often possible to extend the tooth preparation to cover the defect. When the perforation extends into the periodontal ligament, it may be possible to perform periodontal surgery and to smooth off the projecting pin or place a restoration into the perforated area. Certain locations (such as furcations) may not be surgically accessible, and the perforation can cause periodontal problems that ultimately lead to extraction of the tooth.

Lateral perforations can also occur during endodontic treatment or in preparation of the root canal for a post and core. The perforation may be obvious, or it may not be detected initially, becoming apparent only after insertion of the prosthesis. Occasionally these perforations are accessible and can be restored with amalgam, but more often the tooth is lost.

Endodontic treatment is required when pinholes or pins perforate into the pulp chamber.

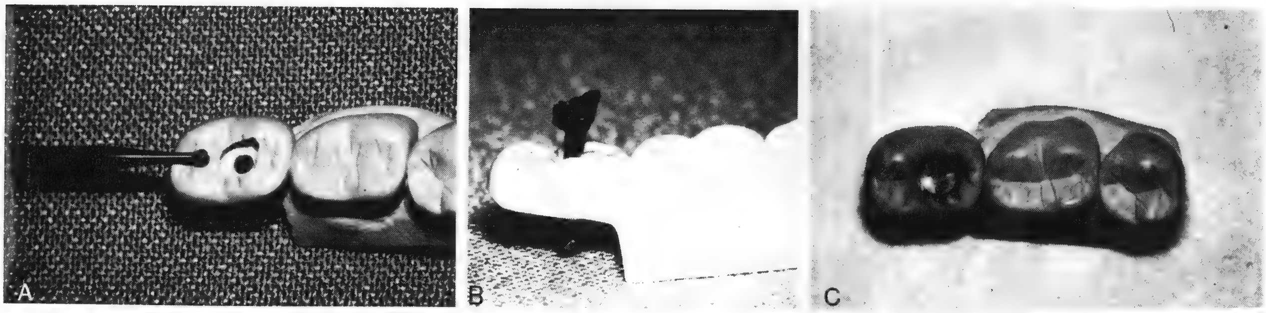


FIGURE 29–8 Inlay Repair of Endodontic Access Opening

A, Working cast of inlay preparation to restore perforation created by endodontic treatment. Because of the small inlay dimensions, a round hole has been placed in the middle of the cervical floor for attachment of a sprue former.
B, Sprue former used to unseat wax pattern for investing.
C, Casting seated on working cast.

MECHANICAL FAILURES

Loss of Retention

A prosthesis can come loose from an abutment tooth, and if this occurrence is not detected early, extensive caries often develops. This loss of retention can be detected in several ways.

The patient may be aware of looseness or sensitivity to temperature or sweets. Also, there may be a recurring bad taste or odor, which must be differentiated from similar symptoms caused by poor oral hygiene or periodontal problems.

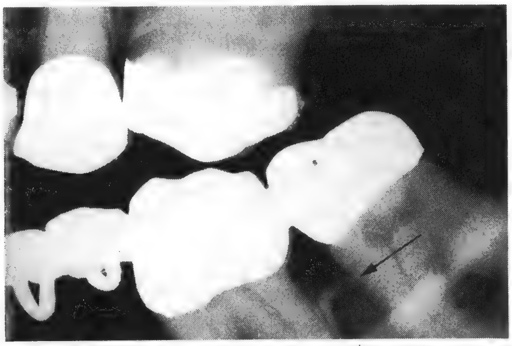


FIGURE 29–9 Prosthesis connector that encroached on a cervical embrasure space and hindered effective oral hygiene, thus promoting bone loss.

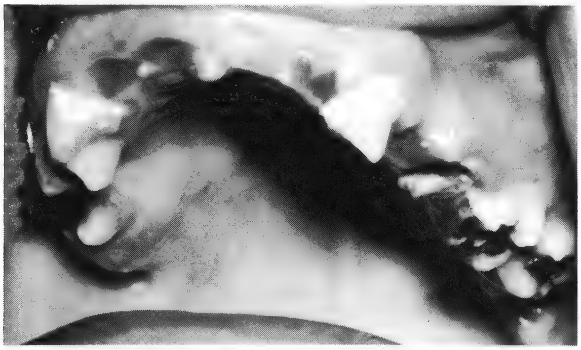


FIGURE 29–10 Unhealthy gingiva caused by pontics that covered too large an area of the edentulous ridge and prevented proper tissue cleaning.

Periodic clinical examinations should include attempts to unseat existing prostheses by lifting the retainers up and down (occlusocervically) while they are held between the fingers and a curved explorer placed under the connector. If a casting is loose, the occlusal motion causes fluids to be drawn under the casting, and when the casting is reseated with a cervical force the fluid is expressed, generally producing bubbles as the air and liquid are simultaneously displaced (Fig. 29–12). When more than two abutment teeth are involved in a prosthesis, it is much more difficult, and sometimes impossible, to detect a single loose retainer. Unfortunately, it is often the presence of obvious clinical problems such as caries that reveals this type of problem.

When a retainer comes loose, the prosthesis must be removed so that the abutment teeth can be evaluated. Occasionally, intact removal of the restoration can be achieved, but at other times removal involves permanent damage to the prosthesis.

If the restoration can be dislodged from other prepared teeth without damage and no caries is present, it is possible to recement the restoration. Improper cementation procedure, such as contamination with moisture, may have caused the problem. However, if prosthesis removal reveals a lack of adequate retention as evidenced by the preparation form, the teeth should be

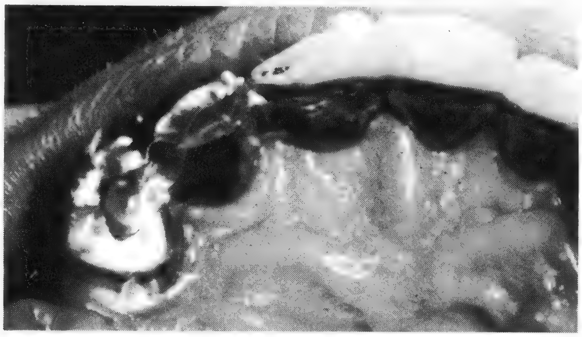


FIGURE 29–11 Heavy centric occlusal contacts caused excessive tooth mobility and large wear facets.

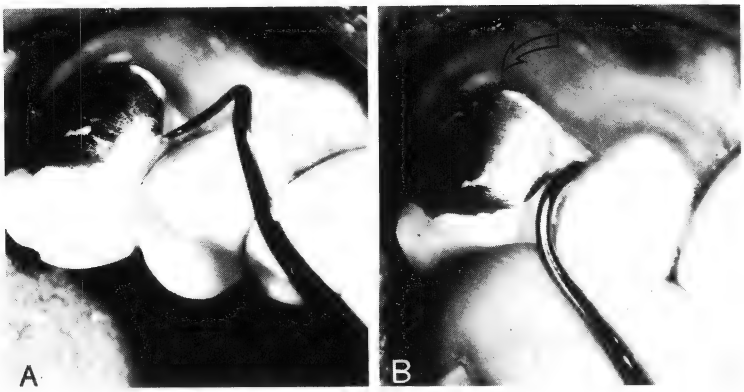


FIGURE 29–12

A, Curved explorer that can be placed under the connector so that an occlusal force can be applied to the retainer.
B, Application of cervical force expresses fluid in the form of bubbles, indicating that the prosthesis is loose.

modified to improve their retention and resistance form, and a new prosthesis should be fabricated (Fig. 29–13).

Some fixed partial dentures come loose even when maximally retentive preparations have been developed. This problem is generally caused by excessive span length or heavy occlusal forces, and a removable partial denture may be the only satisfactory solution.

Connector Failure

A connector between an abutment retainer and a pontic or between two pontics can fracture under occlusal forces. Failures of both cast and soldered connections have been observed and are generally caused by internal porosity that has weakened the metal.

When fracture occurs, pontics are placed in a cantilevered relationship with the retainer casting, and this can allow excessive forces to be developed on the abutment tooth. For this reason, the prosthesis should be removed and remade as soon as possible. Occasionally, an inlaylike dovetailed preparation can be developed in the metal to span the fracture site, and a casting can be cemented to stabilize the prosthesis. If this is not possible and a remake cannot be rapidly accomplished, the pontics should be removed by cutting through the intact connectors. A temporary removable partial denture can then be inserted to maintain the existing space and satisfy esthetic requirements.

Occlusal Wear

Heavy chewing forces, clenching, or bruxism can produce accelerated occlusal wear of a prosthesis. When the occluding surfaces are restored with metal, a casting perforation may develop after several years, since occlusal metal thickness is limited by the allowable amount of tooth reduction (Fig. 29–14). Perforations allow leakage and caries to occur, which ultimately lead to prosthesis failure.

If the perforation is detected early, a gold or amalgam restoration can be placed that seals the area and provides additional years of service. However, if the metal surrounding the perforation is extremely thin, a new prosthesis should be fabricated.

When occlusal surfaces are covered with porcelain, wear of the ceramic material usually is not a problem, even in the presence of heavy occlusal forces. However, when porcelain opposes natural teeth, dramatic wear of enamel may occur, with eventual penetration into the dentin. This problem is exacerbated by heavy chewing forces, clenching, or bruxism and often requires the restoration of the abraded teeth.

The same problem occurs when porcelain opposes metallic restorations. For this reason, in mouths in which occlusal wear is anticipated, it is better to place metal over occluding surfaces when natural teeth or

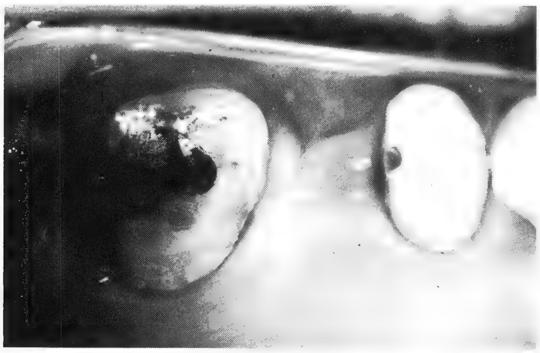


FIGURE 29–13 A prosthesis with partial veneer crown retainers came loose from these prepared teeth. Note the excessive taper to the molar and the lack of proximal boxes or grooves except on the distal of the premolar.

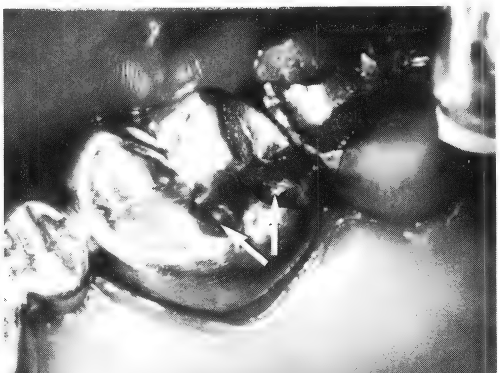


FIGURE 29–14 Arrows indicate small perforations caused by bruxism.

metallic restorations are present in the opposing arch. Although the metal surfaces may wear out over the years, the integrity of opposing tooth structure and metallic restorations is maintained in a more nearly normal state.

Tooth Fracture

Coronal tooth fracture can be dramatic, resulting in considerable loss of tooth structure, or it can be minor with little significant damage. Small coronal tooth fractures often leave the restoration adequately retained, with only the formation of a small marginal defect. This type of problem occurs primarily around inlays and partial-coverage crowns, as the result of wear and the apparent inceasing brittleness of tooth structure with age. If the restoration and tooth structure surrounding the defect can be adequately prepared and still possess sufficient strength, gold foil, amalgam, or resin can be used to restore the area. While this is not ideal, placement of these filling materials can provide many additional years of service. If there is a question regarding the integrity of the remaining tooth structure or restoration, a new prosthesis should be fabricated so that it encompasses the fractured area.

Large coronal fractures around partial-coverage retainers may make it impossible to restore the tooth, but generally a full-coverage restoration can be made. However, the tooth may require a separate pin-retained restoration to serve as a core and provide support and retention for a new prosthesis. If the fracture caused a pulp exposure, endodontic treatment followed by placement of a post and core is necessary prior to fabrication of a new prosthesis.

Abutment tooth fractures under full-coverage retainers usually occur horizontally at the level of the finish line, so that little or no coronal tooth structure is left. This condition necessitates removal of the prosthesis, endodontic therapy, a post and core, and a new prosthesis. However, certain single restorations can be salvaged if the finish line and a little coronal tooth structure remain intact after the fracture. A post and core can be fabricated to fit both the restoration and the prepared tooth. The technique is described here.

An impression is obtained of the prepared root canal and existing finish line. A post is waxed to fit the prepared root canal, and a wax core is built up in small increments to fit the internal surface of the casting. The restoration must be fully seated after the addition of each increment of wax to retain the proper orientation. Proper seating is evaluated by observing the marginal adaptation of the restoration to the finish line on the die. The wax post and core is then cast and adjusted on the working cast to allow complete seating of the restoration.

Several conditions have been known to promote extensive coronal fractures of abutment teeth. Excessive tooth preparation may have left insufficient tooth structure to resist occlusal forces. The preparation may have been composed mostly of restorative material, which was not retained in sound dentin with pins. The presence of interfering centric or eccentric occlusal contacts, or simply heavy occlusal forces on a properly adjusted restoration, can cause fracture. Also, fractures can occur when attempting to forcibly seat an improperly fitting prosthesis or unseat a cemented bridge incorrectly.

Root fractures are often located well below the alveolar bone crest, so that the tooth must be extracted and a new prosthesis fabricated. However, occasionally the fracture terminates at or just below the alveolar bone. In such cases, it may be possible to perform periodontal surgery, remove bone, and expose the fracture site so it can be encompassed by a new prosthesis.

Root fractures are most often caused by trauma. They also can occur during endodontic treatment, forceful seating of a post and core, or the attempt to fully seat an improperly fitting post and core. Unfortunately, fractures occurring during endodontic treatment or post and core insertion may not be immediately apparent and only become detectable with time (Fig. 29–15).

Porcelain Fracture

Porcelain fractures occur with both metal-ceramic and all-ceramic crown restorations. The majority of metal-ceramic fractures can be attributed either to improper design characteristics of the metal framework or to problems related to occlusion. All-ceramic restorations most commonly fail because of deficiencies in the tooth preparation or the presence of heavy occlusal forces.

Metal-Ceramic Porcelain Failures

Framework Design

Sharp angles or extremely rough and irregular areas over the veneering area serve as points of stress concen-

A B

FIGURE 29–15
A, Bite-wing radiograph of prosthesis.
B, A section of fractured root has separated from the post.

FIGURE 29–16 Metal-ceramic crown in which porcelain fractured as a result of underlying perforation in the casting.

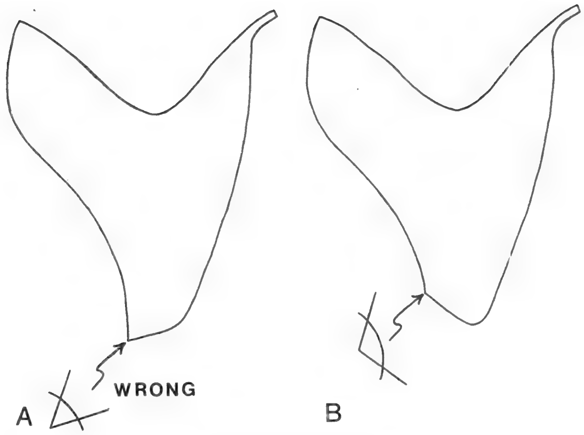


FIGURE 29–18
A, An acute angle frequently leads to porcelain fracture.
B, Correctly formed obtuse angle.

tration that can cause crack propagation and ceramic fracture. Perforations in the metal can also cause failure for the same reason (Fig. 29–16).

An overly thin metal casting does not adequately support porcelain, so that flexure and porcelain fracture are allowed. Trial insertion of the prosthesis, final cementation forces, or postinsertion occlusal forces could produce the failure. When the framework thickness is less than 0.2 mm over large areas of the veneering surface, the potential for failure is much greater regardless of the type of casting alloy.

With facially veneered restorations, porcelain fractures result from a framework design that allows centric occlusal contact on, or immediately next to, the metal-to-ceramic junction (Fig. 29–17). Also, failures occur when the angle between the veneering surface and the nonveneered aspect of the casting is less than 90 degrees (Fig. 29–18). These designs allow occlusal forces to cause localized burnishing of the metal and distortion, which leads to premature porcelain fracture.

Occlusion

The presence of heavy occlusal forces or habits such as clenching and bruxism can cause failure. Centric or eccentric occlusal interferences also place forces on porcelain that are capable of causing fracture (see Fig. 29–11), as do uncorrected occlusal slides, which create deflective contact of the opposing teeth with the prosthesis.

Metal Handling Procedures

Improper handling of the alloy during casting, finishing, or application of the porcelain can lead to metal contamination. Bubbles may form at the metal-ceramic junction when porcelain is applied, creating stress and possibly cracks. Separation of the porcelain from the metal has been observed in cases of severe contamination.

Excessive oxide formation on the alloy surface can also cause separation of the porcelain from the metal. This problem is most frequently caused by improper conditioning of base metal alloys and certain gold-palladium or high-palladium content.

Preparation, Impression, and Insertion

A tooth preparation with a slight undercut can cause binding of the prosthesis as it is seated, which initiates a crack in the porcelain. The fracture may be apparent during try-in but could go unnoticed until premature postinsertion failure occurs. An impression that is slightly distorted can also lead to the same problem.

Teeth prepared with feather-edge finish lines or impressions that do not record all of the finish line can lead to an extension of metal beyond the actual termination of tooth reduction, because the technician cannot

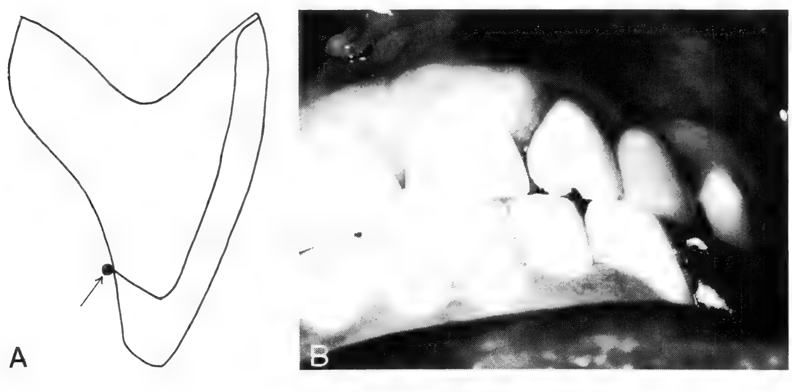


FIGURE 29–17
A, Centric occlusal contact occurring on metal-to-ceramic junction.
B, Prosthesis that failed because contact occurred on the junction.

determine from the die or impression where to terminate the wax pattern. The thin metal may bind against the tooth and initiate a crack in the overlying porcelain. Definite finish lines and impressions that record proper detail are prerequisites to acceptable ceramics.

Attempts to achieve complete seating of a ceramic restoration by using a mallet and wooden stick during trial insertion or cementation can also produce porcelain fracture.

Metal and Porcelain Incompatibility

In rare instances, an alloy and porcelain are found to be truly incompatible, and successful bonding without loss of the veneer or cracking is impossible. However, failure resulting from improper handling of the material is often erroneously attributed to porcelain-metal incompatibility.

Repair of Fractured Metal-Ceramic Restorations

The best method of repairing a fractured metal-ceramic fixed partial denture is the fabrication of a new prosthesis. However, circumstances do not always permit this type of treatment, and procedures are available for repair that have varying degrees of success. They can at least serve in the interim until a new prosthesis is fabricated.

Resin materials are often used to rebuild the porcelain form in the area in which fracture has occurred. Adequate to good color matches can routinely be achieved. Lack of longevity is the main drawback. These materials must be mechanically locked on the porcelain or alloy surface, since true chemical bonding does not occur between the current resins and either metal or porcelain. In locations that are not subjected to heavy occlusal forces and in which good mechanical interlocking is produced, repairs of this nature can last several months or longer. In areas of considerable occlusal force, the resin repair often fails shortly after insertion. Resin repairs can also exhibit color changes that make the repair obvious after a period of time, although a good color match was obtained initially.

A more permanent repair is possible when adequate metal framework thickness is available. The technique works best with facially veneered restorations and involves the following steps: (1) removal of the remaining porcelain on the fractured unit to expose the underlying metal; (2) drilling of several pinholes (4 or 5) into the framework to a depth of at least 2 mm and the making of an impression; (3) creation of a pin-retained metal casting 0.2 to 0.3 mm thick out of a metal-ceramic alloy to fit over the exposed metal framework; (4) fusion of porcelain to the pin-retained casting and reestablishment of normal form; and (5) cementation of the casting in position (Fig. 29–19).

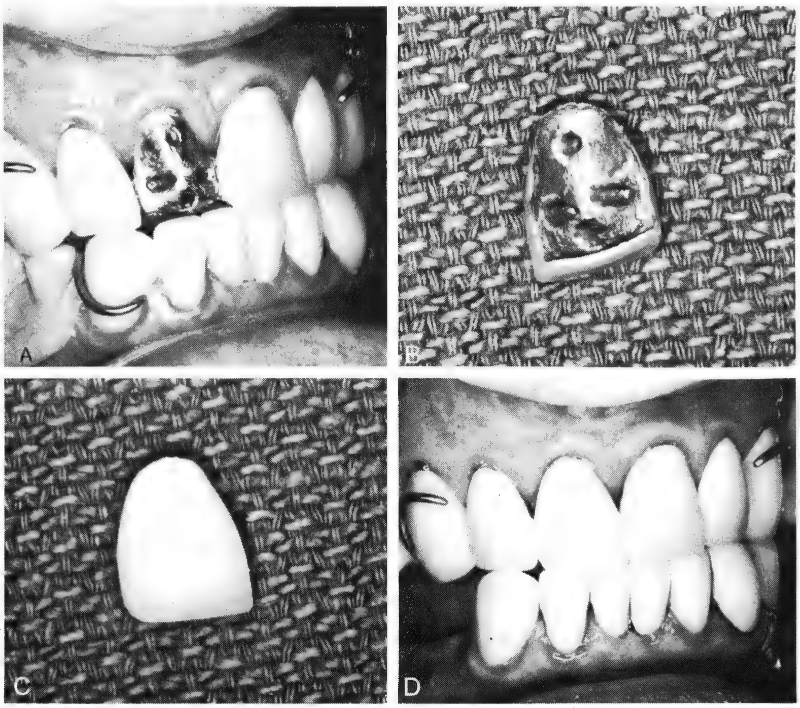
With adequate pin length and a well-fitting casting, these repairs have been known to last many years. Often they can be recemented if they do come loose after a few years.

With full porcelain coverage prosthesis failures, the fractured unit can be prepared with an incisal or occlusal path of insertion, and a staplelike casting can be fabricated and veneered. The preparation should include grooves or pinholes, or both, in the underlying framework to provide retention and stability. A metal-ceramic restoration is then fabricated and cemented in position.

Porcelain Jacket Crown Failures

Since porcelain jacket crowns have been in use for nearly a century, considerable clinical experience relating to their failure is available.

With good tooth preparation, long-term success has



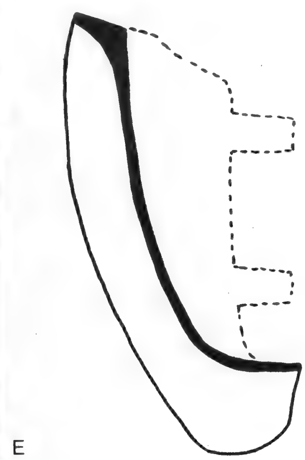


FIGURE 29–19 Repair of Metal-Ceramic Restoration

A, Four pinholes drilled in a metal casting.
B, Lingual view of metal-ceramic pin-retained restoration.
C, Facial view.
D, Repair completed.
E, Diagram showing casting design and veneer of porcelain.

been achieved on incisors, whereas fractures are more frequently observed when these restorations are placed on posterior teeth and on canines because of the occlusal forces on these teeth.

Recently, the development of new materials and techniques has stimulated renewed interest in placement of all-ceramic restorations on canines and posterior teeth. Long-term experience with these materials by a broad spectrum of practitioners is not yet available, but information regarding the potential for failure can be drawn from experiences with porcelain jacket crown failures.

The quality of the tooth preparation and the magnitude of the occlusal forces present are the predominant factors that determine clinical success or failure. All-ceramic restorations are more likely to fail in the presence of heavy occlusal forces, clenching, or bruxism. The tooth preparation must provide adequate, but not excessive, tooth reduction and must be designed to support the restoration, since no metal is present to provide support. The preparation form must be ideal to optimize success.

Vertical Fracture

The marginal area of jacket crowns is often more closely adapted to the prepared tooth than are other areas of the restoration. If a tapered finish line (such as a chamfer) is used, the restoration may contact the tooth on a sloping surface, so that forces are produced that attempt to expand the restoration and that are not well resisted by porcelain. A vertical fracture can occur (Fig. 29–20).

Sharp areas on the prepared tooth, such as the line angles or the incisal edge, produce areas of high stress in the restoration that also can cause vertical fracture.

Vertical fractures have been observed when a large portion of the proximal preparation form is missing and is not restored prior to the impression procedure. When occlusal forces are applied to the marginal ridge in which the missing tooth form is located, greater leverage is developed because of the distance from the point of force application to the underlying prepared tooth. The occlusal forces attempt to rotate the restoration, causing expansive forces. A round preparation form that does not provide adequate resistance to rotational forces can also cause the same type of failure.

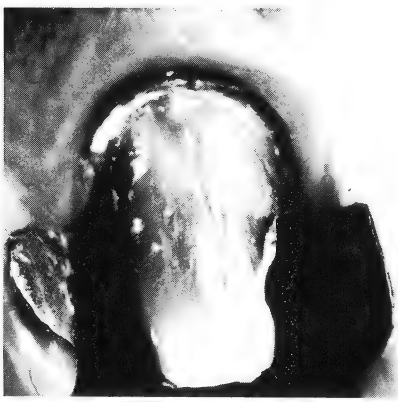


FIGURE 29–20 Tooth preparation for porcelain jacket crown that fractured. Note the chamfer finish line, sharp incisal edge, excessive taper and proximal reduction.

FIGURE 29–21 Short preparation that caused facial cervical semilunar fracture of a jacket crown.

Facial Cervical Fracture

Fracture of the facial cervical porcelain, which often assumes a semilunar form, generally occurs with a short tooth preparation (Fig. 29–21). The incisocervical length of the preparation should be two-thirds to three-quarters that of the final restoration. When the preparation is short, forces applied at the incisal edge attempt to tip the restoration facially and cause cervical porcelain fracture.

When opposing tooth contact is located incisally to the prepared tooth, tipping forces are more frequently developed, with the restoration having a fulcrum on the cervically located incisal edge. This occlusal relationship can also lead to facial cervical porcelain fracture.

Lingual Fracture

Semilunar lingual fractures are observed when the occlusion is located cervically to the cingulum of the preparation, where forces on the porcelain are more shear in nature and not as well resisted (Fig. 29–22).

Other lingual fractures, not necessarily semilunar in form, are the result of inadequate lingual tooth reduction in which less than 1 mm of porcelain is present (Fig. 29–23). Exceptionally heavy occlusal forces also can cause lingual fractures even when adequate porcelain thickness is present.

Dealing with Failures of All-Ceramic Crowns

There are no satisfactory methods for repairing fractures of all-ceramic restorations; a new restoration must be fabricated. If an early failure occurs in the absence of clinical or laboratory defects, occlusal forces are likely to be present that exceed the strength of the restoration. In this case, a metal-ceramic restoration should be seriously considered for the new restoration. If many years of good service occurred prior to failure and optimal esthetics is still required, a new all-ceramic restoration should be considered.

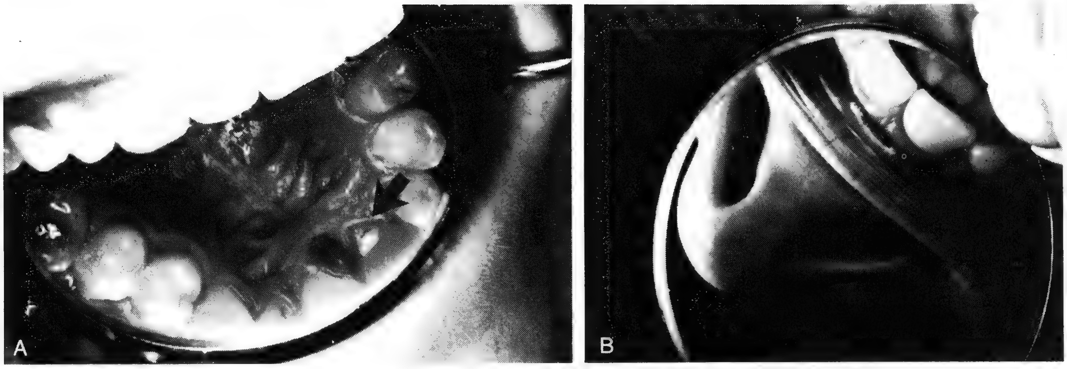


FIGURE 29–22

A, Lingual cervical semilunar fracture.
B, Occlusal contact occurs cervically to the cingulum of the preparation.

ESTHETIC FAILURES

Ceramic restorations more often fail esthetically than mechanically or biologically. Dental laboratories report that remakes occur more frequently because of poor color match than for any other reason.

The unacceptable color match could be the result of the inability to match the patient's natural teeth with available porcelain colors. The shade selection may have been inadequate. Metamerism is an ever present problem that contributes to poor color matching. Insufficient tooth reduction or failure to properly apply and fire the porcelain may have created a restoration that does not match the shade guide or the surrounding teeth.

Esthetic failures also occur because of incorrect form or a framework design that displays metal. In addition, natural teeth undergo color changes that do not occur in porcelain, so that an unacceptable color match is caused over the years.

Partial veneer restorations can be esthetically unacceptable because of overextension of the finish line facially. This displays excessive amounts of metal. Even with proper facial extension, an artificial appearance can be created if the facial outline form of the prepared tooth does not resemble an unprepared tooth. When certain thin incisors are prepared, the metallic color of the partial-coverage casting may be visible through the remaining tooth structure. The grayness becomes more noticeable with time and can present an esthetic problem for certain patients.

FIGURE 29–23 Lingual fracture caused by inadequate lingual tooth reduction and thin porcelain.

The marginal fit or cervical form of a prosthesis can promote plaque accumulation, causing gingival inflammation, which produces an unnatural soft tissue color or form that is esthetically unacceptable.

FACING FAILURES

Manufactured facings have all but disappeared from the market owing to the popularity of metal-ceramics. Nevertheless, fixed partial dentures with porcelain facings are encountered and may require attention. Recementation of a loose facing is a simple process, but when fracture has occurred, a facing repair may be indicated if the prosthesis is otherwise satisfactory.

A new facing can be ground to fit the prosthesis if the particular type of facing is still available. The adaptation of a new facing is done on a trial-and-error basis and often does not yield the ideal fit. However, an acceptable result can be obtained with careful reduction of the porcelain. The fitted facing is cemented in position as usual.

Another repair process is to rebuild the desired form with a resin. Pins can be cemented or threaded into the casting if necessary to facilitate retention of the resin.

It is also possible to prepare the remaining metal casting so that a new pin-retained casting can be fabricated and cemented in place. All-metal or metal-ceramic repairs can be performed in this manner, depending on esthetic requirements.

REMOVAL OF A PROSTHESIS

Many well retained restorations cannot be removed intact and, to prevent abutment tooth damage, must be cut off the prepared tooth and thereby destroyed. Nevertheless, intact removal does occasionally occur, and an attempt to achieve this result can be made. Such re-

FIGURE 29–24 Straight chisel and mallet being used to unseat a prosthesis.

moval is attempted by applying a sharp force in an occlusal direction with a chisel and mallet to tap on the retainer and induce dislodgment (Fig. 29–24). The tapping should be done with the chisel kept as nearly parallel as possible to the path of withdrawal. Sharp blows are required but not so intense as to cause tooth fracture or extreme pain. Commercially manufactured crown removers*† are available that can be placed around retainers or under pontics and connectors so that occlusally directed forces can be applied (Fig. 29–25).

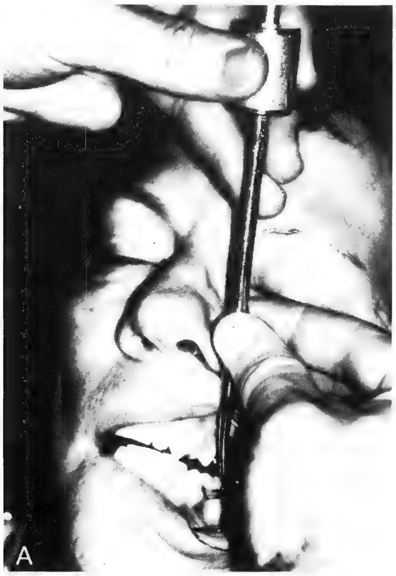
When intact removal is unsuccessful, the prosthesis must be removed by cutting completely through the material until the prepared tooth is exposed. With extracoronal retainers, a thin slot extending from the finish line to the occlusal surface is cut through the restoration (Fig. 29–26A). It is best to locate this slot as close to the center of the facial or lingual surface as access permits. Location of the slot on the lingual surface of anterior metal-ceramic restorations may be advantageous, since the material there is generally thinner (Fig. 29–26B). Also, lingual placement of slots in metal-ceramic restorations makes the temporary repair of the prosthesis cosmetically more acceptable than when a facial approach is used, since many restorations that are cut off can be repaired and used as temporary restorations. A facial slot works best for maxillary and mandibular molars, owing to the more difficult lingual access.

The slot can be efficiently placed by using a high-speed tapered fissure bur (number 700) and copious amounts of a water spray. The flutes rapidly deteriorate, and several burs may be required. Fracturing off a small portion of a dull bur tip creates a new sharp cutting surface and prolongs the cutting life of the bur. A dull bur can be fractured by using the beaks of small pointed orthodontic pliers.

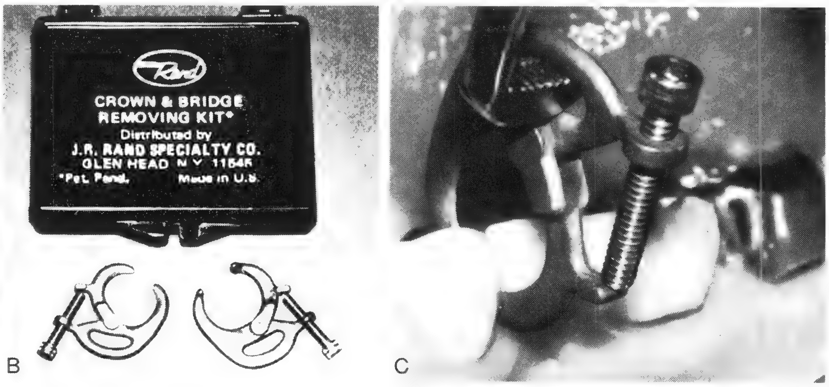
A thin-bladed instrument is placed into the slot and twisted to expand the circumference of the retainer casting and dislodge it from the prepared tooth (Fig. 29–26C, D). A straight elevator, as is used in oral surgery, can be modified so the proper tip form and dimensions are developed. This instrument possesses a handle that is easily grasped. A straight chisel can also be used for this purpose.

*Morrell crown remover, Misdom-Frank Instrument Company, New York, NY 10003.

†Rand crown and bridge removing kit, J. R. Rand Specialty Company, Glen Head, NY 11545.



A



B

C

FIGURE 29–25 Commercial Crown Removers

A, Crown remover with a cylindric metal weight that slides along a shaft until it hits the rim at the top of the shaft to produce a sharp tap.
B, Prosthesis-removing kit.
C, Screw tightened to stabilize remover so tip of instrument shown in (A) can deliver a sharp blow.

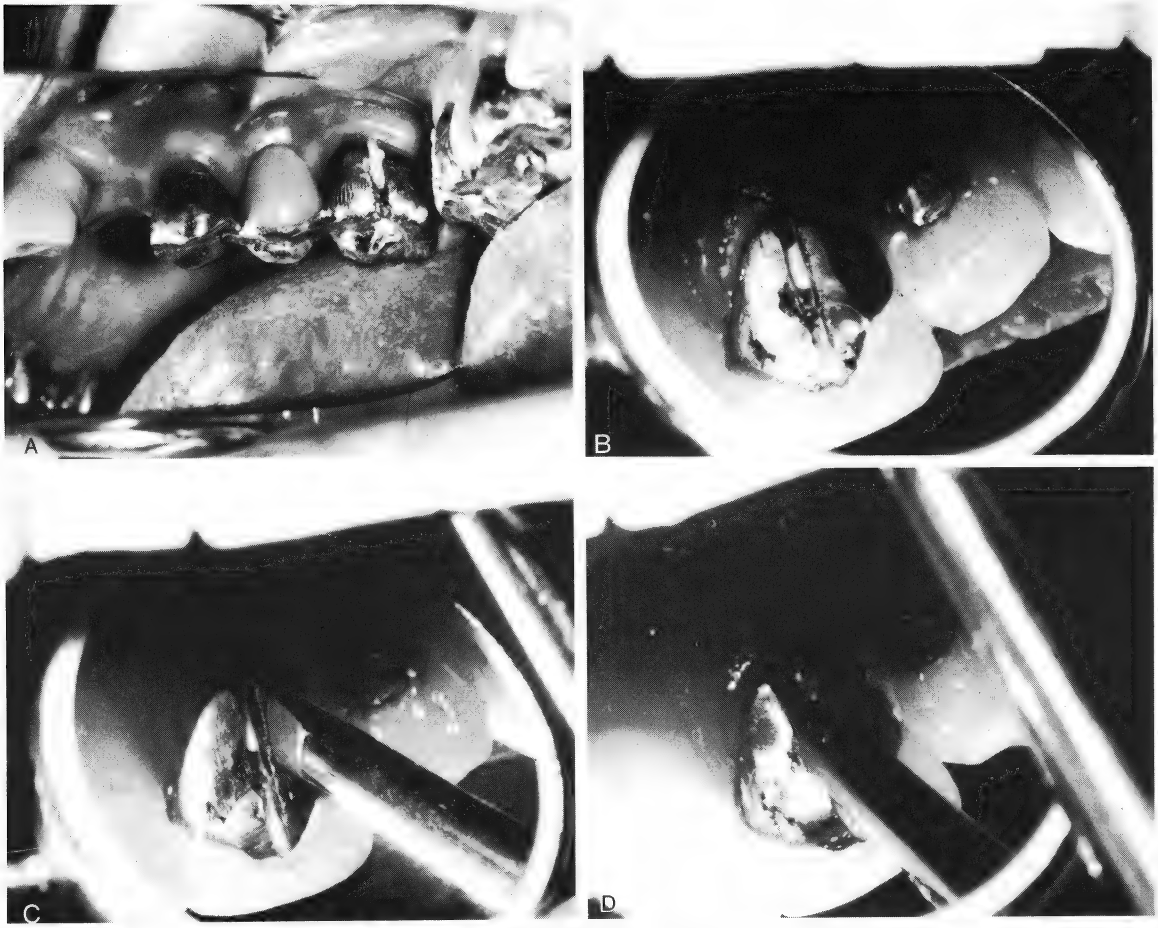


FIGURE 29–26 Removal Slot

A, Completed slot formed with tapered fissure bur.
B, Lingual slot in central incisor metal-ceramic restoration.
C, D, Modified straight elevator placed into slot.

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Restorations to Aid the Support and Retention of Removable Prostheses

Removable prostheses are fabricated for reasons of appearance, mastication, speech clarity, and general well-being. At the same time, they must preserve remaining teeth, alveolar bone, gingival tissue, and tooth position by bringing the forces acting on the removable prosthesis within the limits of tissue tolerance. Satisfying these objectives may require the use of single crowns or fixed partial dentures with specific contours that provide the necessary support and retention for the prosthesis.

Restorations are also used in conjunction with removable partial dentures to (1) re-establish the integrity of carious or extensively restored abutment teeth; (2) eliminate modification spaces that can complicate design, tolerance, or maintenance, or interfere with the most desirable path of insertion; (3) eliminate coronal contours that would otherwise interfere when the rigid portion of the partial denture framework is inserted or removed; (4) restore occlusion; (5) establish an acceptable occlusal plane; (6) improve the esthetic result; (7) splint teeth; and (8) provide recesses that accept intracoronal attachments so the use of visible clasps can be avoided.

RESTORATION CONTOURS THAT PROVIDE SUPPORT AND RETENTION

Guiding planes or flattened areas are formed on restorations, parallel to the path of insertion, for the purpose of promoting orientation of the prosthesis during insertion. They also provide reciprocation against forces that attempt to push teeth out of position during insertion and removal or during functional movement of the prosthesis.

Undercut areas are created into which the flexible tips of retentive clasps can be inserted. The undercut location varies with the particular type of retentive clasp being used. These areas aid prosthesis retention and stability as the clasp tip engages tooth contours occlusal to the undercut area when forces attempt to unseat the partial denture.

The restoration contour must also provide for a rest seat that halts cervical movement of the prosthesis during insertion and mastication.

RESTORATIONS FOR CLASP-RETAINED REMOVABLE PARTIAL DENTURES

Before tooth preparation is started, diagnostic casts should be analyzed by using a dental surveyor (Fig. 30–1) and the appropriate tools (Fig. 30–2). The path of insertion is established with the analyzing rod (Figs. 30–2 and 30–3). At the same time, the amount of required recontouring of abutment teeth can be evaluated with the analyzing rod. As the rod is drawn around the circumference of a tooth, it contacts the height of contour and indicates the survey line, which can then be marked with the carbon rod (Figs. 30–2 and 30–3). The location of areas cervical to the survey line (undercut areas) can be identified and their depth measured with the undercut gauges (Fig. 30–2).

Abutment tooth reduction is guided by the predetermined path of insertion so that any required restorations

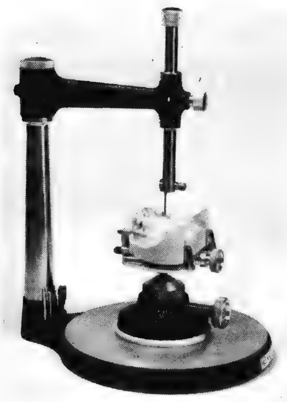


FIGURE 30–1 The Ney Surveyor and surveying table.

possess the proper crown contour while a material thickness is maintained that allows strength and esthetics.

Tooth Preparation

When teeth are prepared for restorations that must serve as removable partial denture retainers, the existing crown form should first be modified to provide prosthesis support and retention. Then the tooth is prepared for the indicated type of single crown or fixed partial denture. This procedure of modifying tooth contours and then preparing the tooth ensures that adequate space is provided so the restoration possesses the contours specifically required by the removable prosthesis. Also, this method is particularly helpful for the user who is first learning to prepare removable partial denture abutment teeth, since it is difficult to visualize restoration shape and compensate for required contour changes by additional tooth reduction.

Modifying Existing Crown Contour

Tooth surfaces that interfere with the path of insertion should be reduced, and guiding planes should be placed wherever needed (Fig. 30–4A, B). Adequate space must also be provided so that a properly sized rest seat can be developed in the restoration. If an occlusal rest is being used, as on posterior teeth, a proximal box is located faciolingually in a position approximately centered over the crest of the edentulous ridge. The box ideally should measure 4 mm faciolingually, 2.5 mm occlusocervically, and 3 mm mesiodistally (Fig. 30–4C). Box dimensions may have to be reduced when occlusal rests are placed in small premolars or anterior teeth.

When a cingulum rest is being used on an anterior tooth, a ledge 1.5 mm wide should be prepared in the proper area of the cingulum (Fig. 30–5). When circumferential clasps are to be used in a back-to-back relationship, ledges 2 mm wide mesiodistally and 3 mm deep occlusocervically should be prepared in the marginal ridge area of both abutment teeth and extending the full faciolingual length of the proximal surface (Fig. 30–6A, B).

Reduction for the Restoration

Finally, the tooth is reduced axially and occlusally in accordance with the usual preparation guidelines for the specific type of abutment retainer being used (Figs. 30–4D and 30–6C). No additional reduction is required in areas in which space has been created for rest seats.

Wax Pattern Formation

On the mounted working cast, a full-contour wax pattern first must be developed that is esthetically harmonious with other teeth, possesses normal cervical contour, and occludes properly with opposing teeth. Only when this has been accomplished should consideration be given to specific shape modifications necessary to eliminate path of insertion interferences and produce guide planes, retentive undercuts, and rest seats.

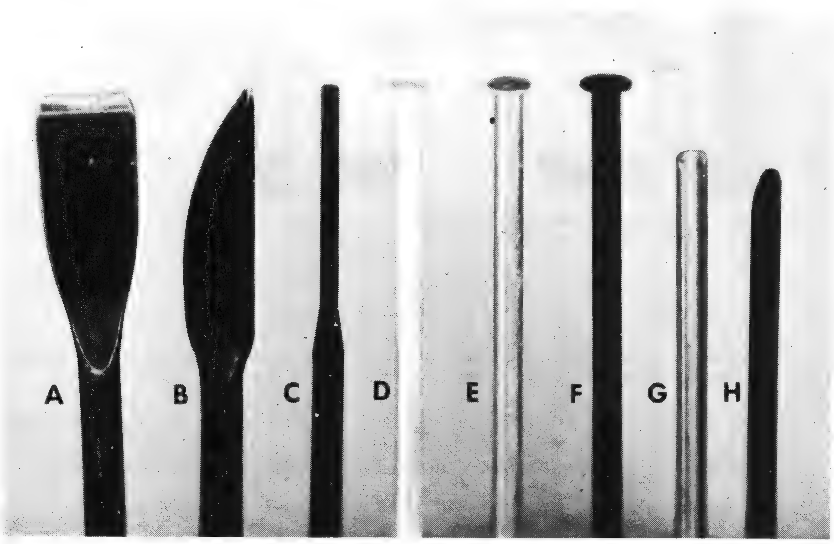


FIGURE 30–2 Tools To Be Used with the Ney Surveyor
A, B, Wax trimmers.
C, Analyzing rod.
D, E, F, Undercut measuring gauges, 0.010, 0.020, and 0.030 inches, respectively.
G, Protective metal sheath for carbon marking rod.
H, Carbon marking rod.

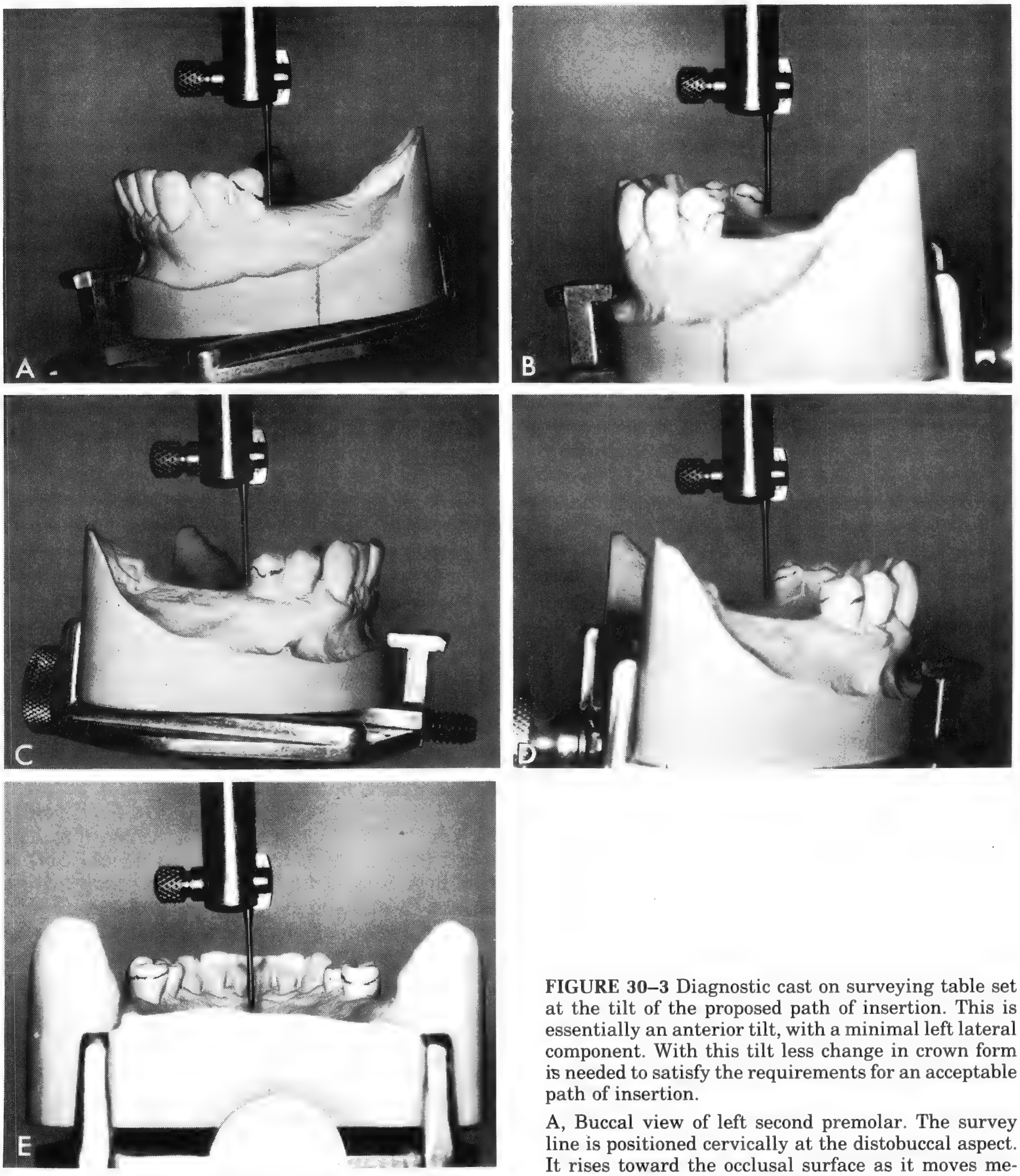


FIGURE 30–3 Diagnostic cast on surveying table set at the tilt of the proposed path of insertion. This is essentially an anterior tilt, with a minimal left lateral component. With this tilt less change in crown form is needed to satisfy the requirements for an acceptable path of insertion.

A, Buccal view of left second premolar. The survey line is positioned cervically at the distobuccal aspect. It rises toward the occlusal surface as it moves mesially. This makes mesiobuccal retention possible, yet permits the bracing portion of the retentive clasp to be placed low on the tooth while remaining above the survey line. A slight modification of the distal surface creates a guiding plane.

B, Lingual view of the right second premolar. The survey line is low distolingually. With some modification, the mesiolingual and the lingual surfaces can be made parallel to the path of insertion and function as a guiding plane to provide reciprocation for the lingual bracing arm.

C, Buccal view of the right second premolar. The survey line is too high distobuccally. The bulge must be placed lower but must still keep the bracing section above the survey line. Adequate retention is available mesiobuccally.

D, Lingual view of the left second premolar. The survey line is quite high. This surface requires considerable alteration in contour to make it parallel to the path of insertion so that it may function as an area for reciprocation.

E, Distal view of both proposed abutments. Some alteration of contour is necessary to remove small undercuts on the distal surfaces so that these surfaces will be parallel to the path of insertion and function as guiding planes.

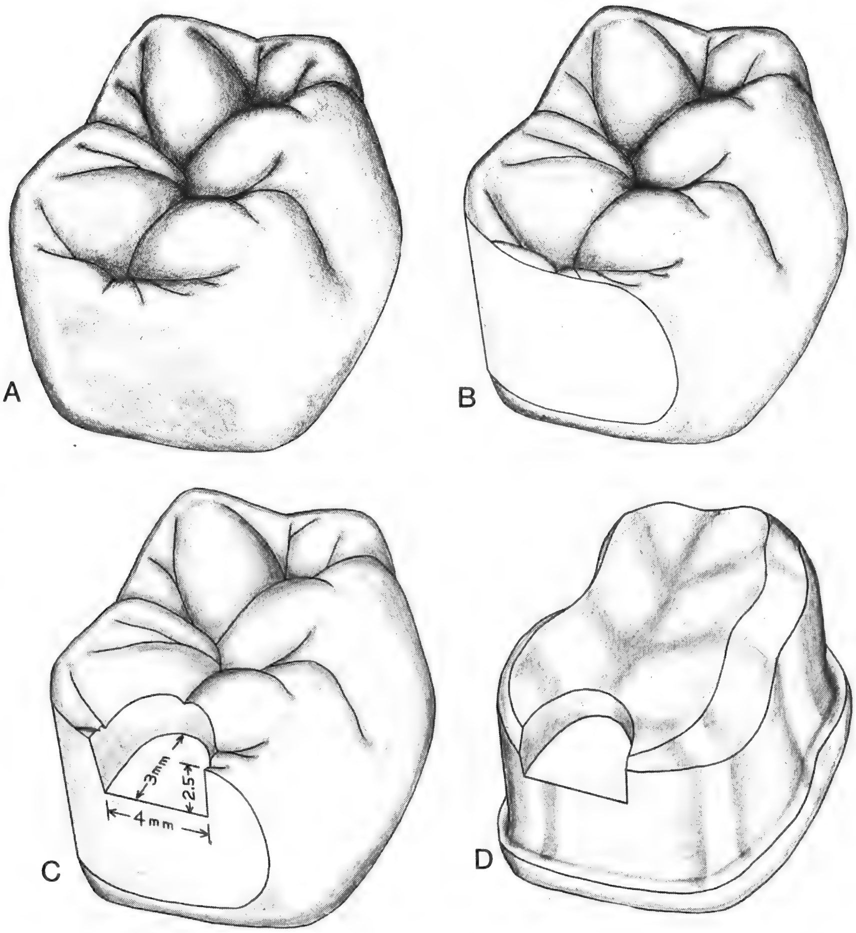


FIGURE 30–4 Preparation Sequence for a Mandibular Molar in which an occlusal rest will be placed in a full veneer crown

A, Tooth prior to preparation.
B, Proximal and lingual guiding planes formed.
C, Proximal box placed where occlusal rest is to be located.
D, Full veneer crown preparation completed.

Selecting the Path of Insertion

When the treatment plan was formulated, a tentative path of insertion was chosen, which should now be confirmed by placing the working cast in a surveyor and using the analyzing rod. The best path of insertion is one that allows proper support and retention to be developed with the least amount of change in existing wax contours. When the abutment teeth are in normal alignment, generally the path is close to the average of their long-axis inclinations. In other words, the most desirable path of insertion would be perpendicular to the plane of occlusion (Fig. 30–7).

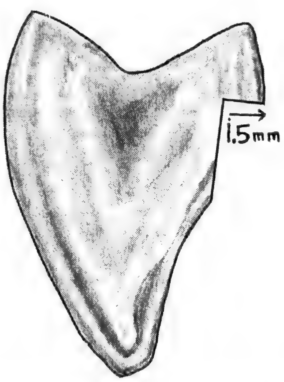


FIGURE 30–5 Maxillary canine showing ledge prepared in cingulum so a cingulum rest can be formed in the restoration.

When considerable alignment deviation is present, a path favorable to the most anterior abutment is used, both because esthetic requirements often prohibit major alterations in anterior teeth contours and because posterior teeth are larger and more easily altered. Also, if enamel modifications have been completed on teeth not to be restored with crowns, they would usually have been completed prior to other abutment retainer preparations, and the path of insertion thus would be recorded on the cast.

If the clasp being used requires a mesially located undercut, tilting of the cast anteriorly in the surveyor increases the amount of undercut available with a given tooth contour. Likewise, when a distal undercut is wanted, tilting of the cast posteriorly increases the available undercut. Conversely, when an excessive undercut exists with the present contour, the survey line can be relocated by tilting the cast away from the undercut area. Altering the lateral tilt also raises or lowers the survey line representing the height of contour and increases or decreases the amount of undercut.

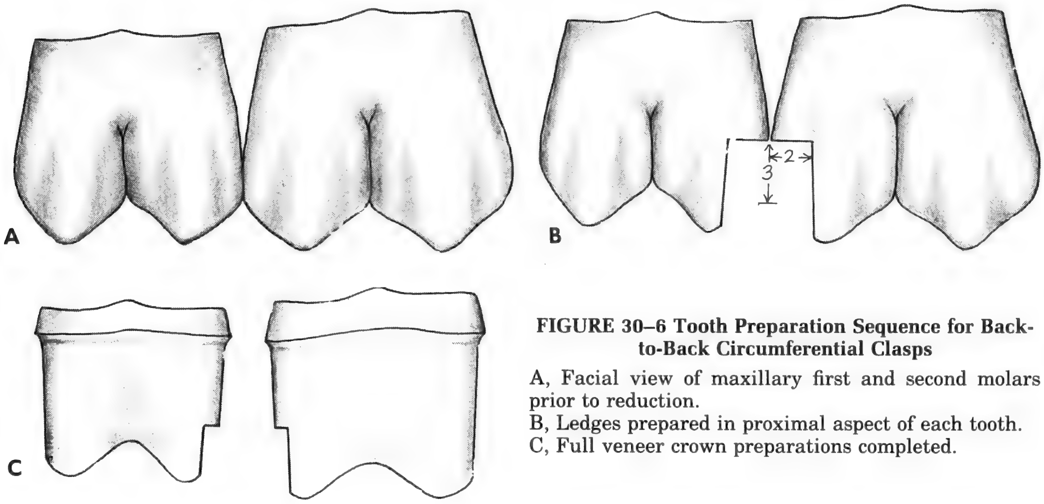


FIGURE 30–6 Tooth Preparation Sequence for Back-to-Back Circumferential Clasps

A, Facial view of maxillary first and second molars prior to reduction.
B, Ledges prepared in proximal aspect of each tooth.
C, Full veneer crown preparations completed.

It must be remembered that every change in tilt affects all teeth equally, and the path of insertion finally selected may be a compromise that is not the ideal path for any of the abutments.

The path of insertion is marked on one side and on the back of the cast by scribing a line alongside the analyzing rod with a pencil (see Fig. 30–3A, B). These marks allow the surveying table to be readjusted to the desired path of insertion should the locking mechanism come loose or the table be needed for another patient's treatment.

Reshaping the Wax Pattern

Ordinarily, contour changes that are made to improve the stability or retention of a removable partial denture should result in a reduction of tooth size rather than an increase.

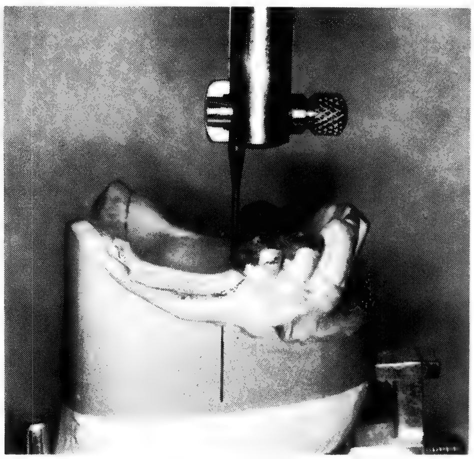


FIGURE 30–7 Selecting the path of insertion for the removable partial denture. The wax patterns have been dusted with zinc stearate so that survey lines are visible. The tilt selected has been marked on the base of the cast. The height of contour on the mesial two-thirds of the buccal surface is adequate for the circumferential clasp that is to be used. The survey line on the distal one-third must be lowered.

Clasps and other partial denture framework components have the effect of increasing crown size, which is one of the unavoidable disadvantages of clasp-retained removable partial dentures. This consequence can be lessened by reducing tooth size rather than bulging it out when the survey line location is altered and when guiding planes are made. Nevertheless, situations exist in which there are inadequate undercut areas because of insufficient protuberance in tooth contour and there is no other choice but to increase tooth dimension.

Producing the Proximal Guiding Plane

Guiding planes may be cut on a wax pattern by any one of a number of instruments. Hand carvers are used by some technicians, with the results being merely checked by a surveyor.

Guiding planes can also be carved into the wax with a surveyor and accessory cutting blade, which is aligned parallel to the path of insertion. The blade is brought into contact with the pattern, and the surveying table is moved so that it drags the pattern across the blade (Fig. 30–8A, B). Care must be exercised not to break the brittle pattern. Guiding planes should be cut smoothly into the wax to minimize the amount of finishing that is required in the casting. A proximal guiding plane should be flat occlusocervically (Fig. 30–9A). Buccolingually it should follow the original curved contour of the tooth so that there are no sharp line angles that would tend to weaken clasp arms fitted to them. A guiding plane should be of such length that it is contacted by the partial denture framework prior to, or simultaneously with, the contact made by the retentive clasp tip as the prosthesis is being seated.

Contouring Pattern for the Retentive Clasp

With the aid of the surveyor analyzing rod, the height of contour is checked on the surface that is to be contacted by the retentive arm of the clasp. The survey line can be seen on the wax if the pattern is dusted with zinc stearate powder and the analyzing rod is drawn across the surface. The contact of the rod with the area

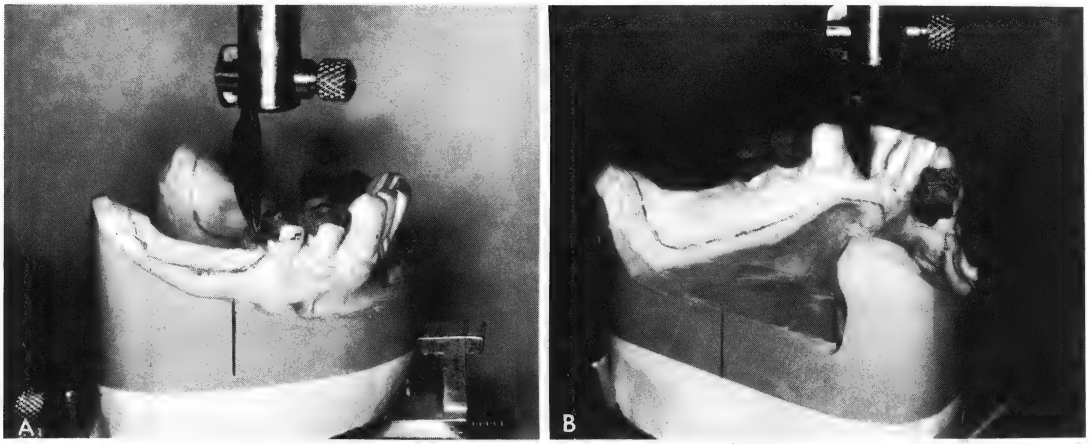


FIGURE 30–8 Forming the Guiding Plane

A, The carving blade being used to trim wax from the distal surface of the pattern.
B, Guiding plane formed on the distal surface.

of greatest convexity removes the powder and marks the survey line. The form and occlusocervical height of the survey line are adjusted to meet the requirements of the type of retentive clasp being used.

For a *circumferential clasp* approaching the tooth from the distal aspect, the survey line should be low distally and rise mesially in the form of a gentle curve to provide a mesial retentive undercut (Fig. 30–10). With a *T-bar clasp* utilizing a distal undercut, the reverse is in order (Fig. 30–11). An *I-bar clasp* requires a survey line that develops an undercut in the gingival one-third located slightly mesial to the mesiodistal center of the tooth (Fig. 30–12).

The undercut depth at which the tip of the retentive clasp is to be located is measured with an undercut gauge in the surveyor (Fig. 30–13). The pattern survey line is brought into contact with the shank of the gauge, and the vertical spindle of the surveyor is raised until

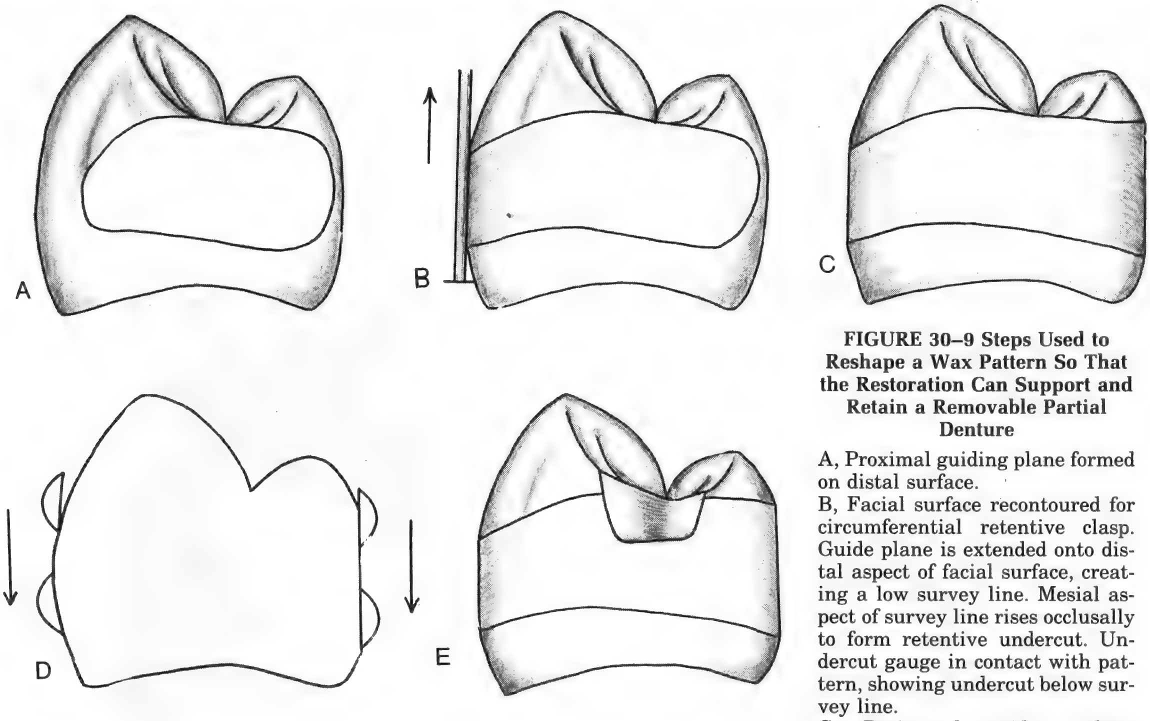


FIGURE 30–9 Steps Used to Reshape a Wax Pattern So That the Restoration Can Support and Retain a Removable Partial Denture

A, Proximal guiding plane formed on distal surface.
B, Facial surface recontoured for circumferential retentive clasp. Guide plane is extended onto distal aspect of facial surface, creating a low survey line. Mesial aspect of survey line rises occlusally to form retentive undercut. Undercut gauge in contact with pattern, showing undercut below survey line.
C, Reciprocal guiding plane formed on lingual surface.
D, Cross section through undercut area. At the beginning of insertion, the lingual reciprocating clasp arm is contacting the guiding plane when the facial retentive clasp contacts the tooth and begins to flex. After seating, the facial clasp has flexed over the height of contour and is located in the undercut with the lingual reciprocal arm still contacting the guiding plane.
E, Occlusal rest carved into marginal ridge and occlusal portion of proximal guiding plane.

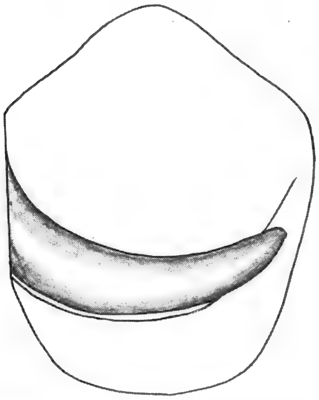


FIGURE 30–10 Survey Line Required for Circumferential Retentive Clasp

Facial survey line located low distally and rising mesially to create a mesial cervical undercut. Circumferential clasp in position showing tip located in undercut.

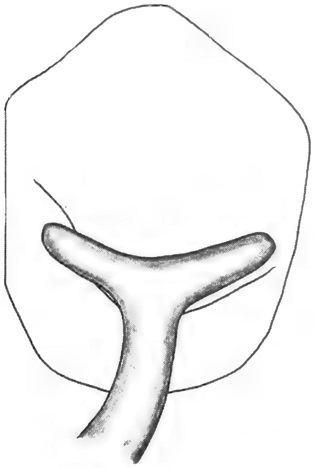


FIGURE 30–11 Survey Line Required for a T-Shaped Bar Retentive Clasp

Facial survey line located low mesially and rising distally to create a distal cervical undercut. T-bar clasp in position showing distal tip located in undercut.

the flange of the gauge just contacts the pattern (see Fig. 30–9B). The point at which the flange makes contact is the location of an undercut equal in depth to the size of the gauge. The depth most frequently used is 0.25 mm (0.010 inch). When the undercut in the "infrabulge" area is too deep, the flange of the gauge does not contact the pattern when the shank touches the survey line; this situation necessitates removal of wax at the survey line with a hand instrument or a cutting blade in the surveyor. Next the proper occlusocervical convexity at the survey line is reestablished by rounding the surface both occlusally and cervically to the carved area. If the undercut is shallow, wax must be added until the survey line exhibits adequate protuberance relative to the area in which the retentive clasp tip is to be located.

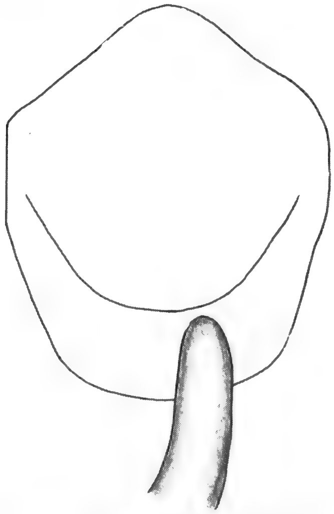


FIGURE 30–12 Survey Line Required for an I-Shaped Bar Retentive Clasp

Facial survey line forming undercut in cervical one-third of crown. I-bar clasp located in cervical undercut and slightly mesial to center of tooth.

Contouring Pattern for Reciprocating Clasp Arm

A reciprocal guiding plane is carved in the area opposite to the tip of the retentive clasp (180 degrees around the tooth) (see Fig. 30–9C). For a *circumferential clasp* retained mesiobuccally, a distolingual guiding plane should be formed to be continuous with the proximal guiding plane (Fig. 30–14). When a *T-bar clasp* with distobuccal retention is used, the reciprocal plane is made in the mesiolingual line angle of the tooth. Regardless of the clasp that is used, the survey line for the surface to be contacted by the reciprocal portion should be low on the tooth. The optimal location for the inferior border of the reciprocal arm is about 1.0 mm occlusal to the gingival crest in order to produce a

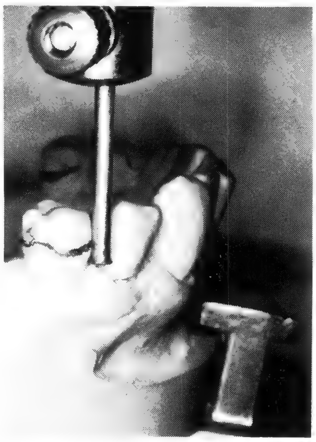


FIGURE 30–13 Undercut gauge being used on stone cast. Note that the shank of the gauge contacts the survey line; the contact of the flange with undercut areas shows where the tip of the retentive clasp is to be located.

FIGURE 30–14 Forming the lingual reciprocal guiding plane for a circumferential clasp. It is continuous with the distal guiding plane. The same cutting instrument is used.

reciprocating plane that is long enough to make contact with the framework before the retentive clasp begins to flex as it passes over the "suprabulge" portion of the tooth (see Fig. 30–9D).

When anterior teeth are clasped and a lingual plate is used as the indirect retainer, the cingulum is overcontoured into a reciprocal guiding plane that extends to within 0.5 mm of the gingiva.

Producing the Supporting Area

Occlusal rests are carved into the marginal ridge area and the occlusal portion of the proximal guiding plane (see Fig. 30–9E). Their mesiodistal form should resemble the tip of a spoon (Fig. 30–15). Occlusal rests can be cut into the wax with a spoon excavator or a hand-held number 6 or 8 straight handpiece bur. If a round bur is used, refinement is necessary to achieve the spoon shape and to ensure adequate thickness in the framework casting where it crosses the marginal ridge of the rest seat. The finished rest seat should ideally have the following dimensions: 1.5 mm occlusocervically where it crosses the marginal ridge, 2.5 mm mesiodistally, and 3.0 mm faciolingually (Fig. 30–16). The floor of the rest

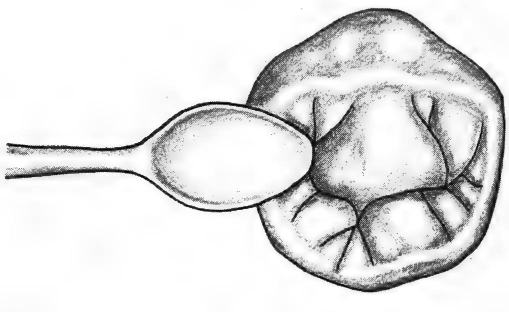


FIGURE 30–15 The mesiodistal form of an occlusal rest should resemble the tip of a spoon.

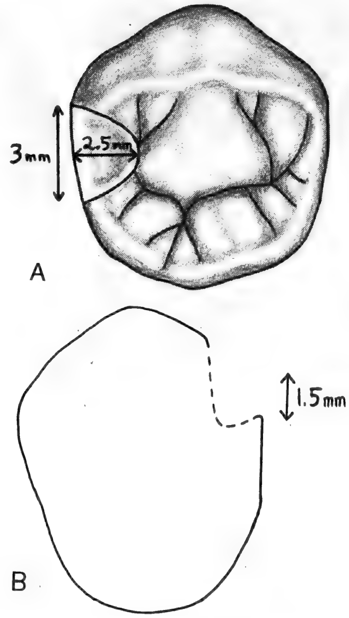


FIGURE 30–16
A, B, Proper rest seat dimensions and form.

seat should slope cervically from the marginal ridge toward the center of the tooth for a distance of 1.5 mm.

For placement of a rest seat on an anterior tooth, the cingulum and marginal ridge should be raised occlusally in the wax pattern to make room for the seat, which also increases the height of the proximal guiding plane (Fig. 30–17). Even with these contour changes, it is often difficult to attain the ideal dimensions on anterior teeth, and it may be necessary to reduce the rest seat size. On occasion, available space may even require recontouring of the opposing teeth.

When circumferential clasps are to be placed back-to-back, the supporting area in each tooth is a ledge placed in the marginal ridge area of the proximal surface. This may be carved in the pattern with a hoe or chisel. The ledge on each tooth should be 1.5 mm wide mesiodistally and 2.0 deep occlusocervically and should gently curve around the proximofacial and proximolingual line angles, gradually fading out as it passes these line angles. The floor of each ledge should slope cervically from the marginal ridge toward the center of the tooth. Proximal contact must be established just cervical to the carved ledges to keep tooth relationships stable before the partial denture is inserted and subsequently when the prosthesis is relined or at other times when the patient is not using it (Fig. 30–18).

When a lingual ledge is being used on an anterior tooth, a hoe or chisel is used to carve the ledge into the pattern. It should be located occlusocervically at the center of the cingulum and extend at least 1 mm facially toward the center of the tooth. The ledge width gradually tapers out as it crosses the mesial and distal marginal ridges (Fig. 30–19). It should incline slightly toward the center of the tooth to transmit force in that direction (Fig. 30–20).

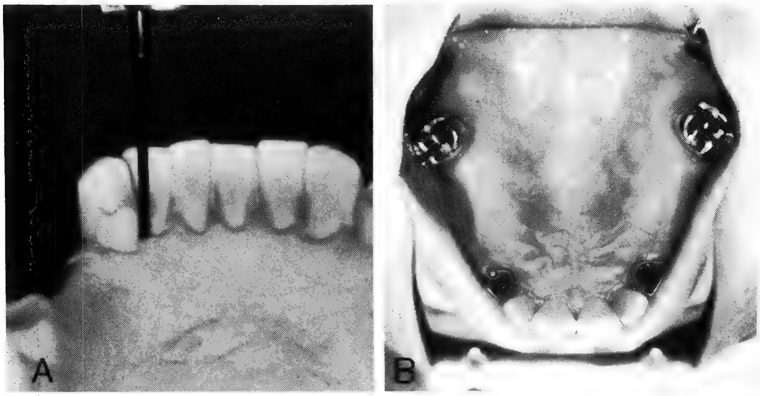


FIGURE 30–17
A, B, Anterior rest seats. The cingula and distal marginal ridges have been built up to allow rest seats of proper size.

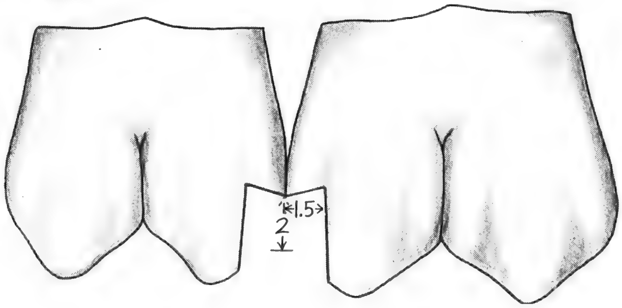


FIGURE 30–18 Form and dimensions of supporting areas for back-to-back circumferential clasps.

By the same techniques, rest areas are formed in restorations to receive indirect retainers or other secondary occlusal rests. There must be a guiding plane below each rest area to help direct the seating of the partial denture and to resist some of the lateral forces during its function.

After all contour changes have been made, the cast is returned to the articulator for rechecking and refining of the occlusion.

Metal-Ceramic Wax Patterns

It is advantageous to design metal-ceramic restorations with a facial veneer of porcelain rather than full porcelain coverage. This allows for easier development of desired restoration contour modifications, since they are located primarily in metal rather than in porcelain.

A full-contour wax pattern is formed and then altered so that it possesses the required guiding planes and retentive undercut. Next, the supporting area is carved into the pattern. At least 1 mm of wax should remain between the periphery of the rest seat and wherever the metal-porcelain junction is to be located (Fig. 30–21).

The facial surface is then reduced to create space for porcelain, and the margins are refined on the die in the usual manner.

Investing and Casting Procedures

The thought and effort used to shape wax patterns for restorations that can properly support and retain a

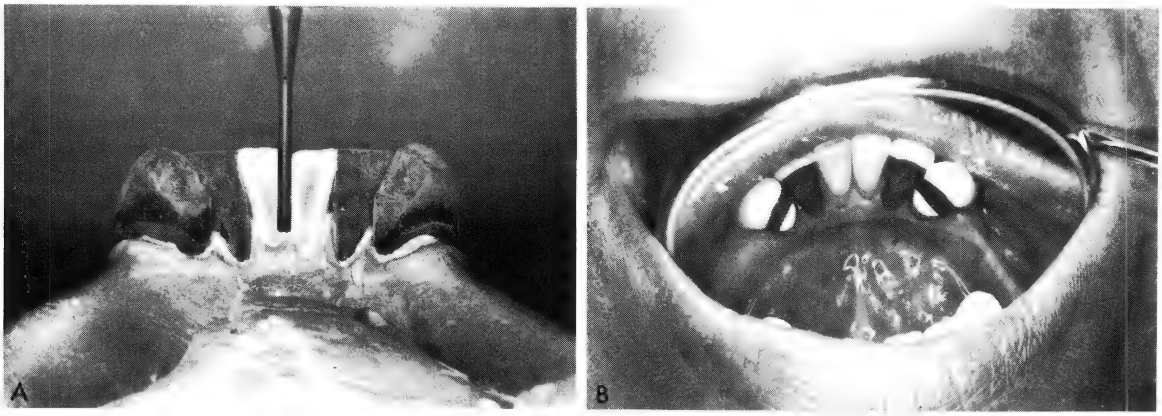


FIGURE 30–19
A, B, Cingulum ledge produced to support a lingual plate.

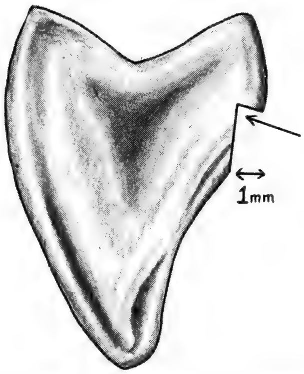


FIGURE 30–20 Lingual ledge carved in maxillary canine wax pattern. Note that the cervical floor is inclined toward the center of the tooth.

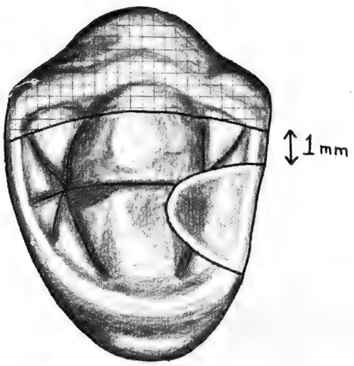


FIGURE 30–21 Metal-ceramic wax pattern showing 1 mm of wax retained between rest seat and metal-ceramic junction.

removable partial denture should be followed by equally precise investing and casting techniques. The wax pattern should be complete in all details before it is invested. The surface must be smooth and without flaws to avoid prolonged finishing of the casting, which could detrimentally alter established contours.

Refining the Casting

The castings are made, removed from the investment, and cleaned as usual. They are checked for fit on the die and placed on the articulated cast for the adjustment of proximal and occlusal contacts. The working cast is returned to the surveyor, the cast is realigned according to the previously determined path of insertion, and the contours are evaluated with the analyzing rod and appropriate undercut gauge (Fig. 30–22). A parallel-walled Carborundum stone or plain fissure bur is placed in a straight dental handpiece, which is attached to the surveyor by a handpiece holder* and used in refining the guiding planes (Figs. 30–23 and 30–24). These instruments, when used judiciously, leave a surface that requires only minimal polishing.

Spoon-shaped rest seats are smoothed and polished using round burs of the appropriate size (Fig. 30–25).

If contour requirements, as disclosed by the survey analysis, have been satisfied, the surface texture of the restoration is finished to its ultimate state with progressively finer abrasive discs or rubber polishing instruments, with care being taken not to create appreciable changes in contour. The marginal areas are finished on the stone die, and tripoli and rouge are used to achieve the final lustre. After polishing, crown contours are again checked with the surveyor to make certain that no change in shape has occurred (Fig. 30–26).

If the abutment restorations are part of a splint or bridge, any remaining assembly procedures are completed at this time, after which a final check with the survey should be made. The castings are then ready for clinical try-in, adjustment, and cementation.

Refining Metal-Ceramic Restorations for Clasping

After an adequate bulk of porcelain has been fired, the restoration is shaped to establish proper esthetic form and proximal and occlusal contact. The working

*The J. M. Ney Company, Bloomfield, CT 06002.

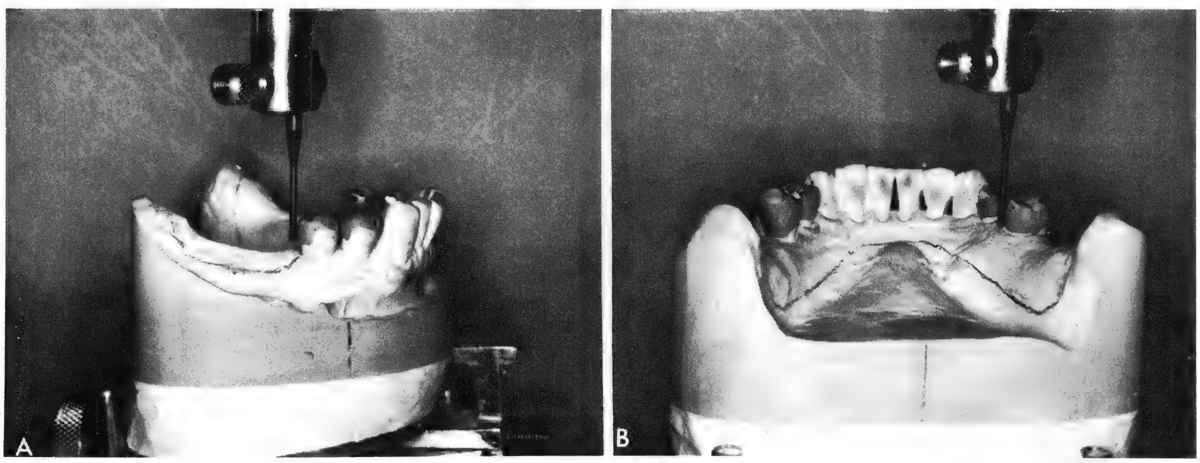


FIGURE 30–22
A, B, Verifying the contours of the castings.

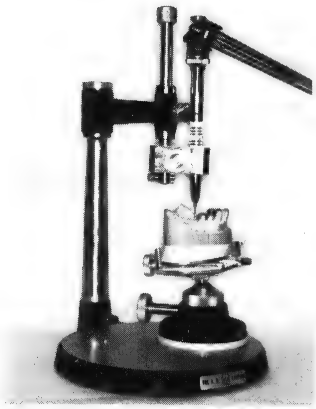


FIGURE 30–23 The Ney Surveyor with handpiece attachment.

cast is then placed in the surveying table and aligned with the path of insertion so that rotary instruments can be used to refine the guiding planes. It is best to use different instruments to shape the porcelain and the metal, respectively. This procedure avoids contamination of the porcelain surface with metal particles, which often occurs when an instrument used on metal is also used on porcelain. The metal particles become embedded in the porcelain and cause discoloration upon glazing. Diamond instruments are particularly well suited for shaping porcelain, whereas the usual Carborundum stones or carbide burs can be used on the metal.

Some cross-contamination is inevitable as the metal-ceramic junction is crossed, but with careful grinding it can be confined to only this area. The contaminated area can be cleansed by regrinding with a clean diamond instrument while metal contact is avoided.

The proper occlusocervical convexity at the survey line is established by grinding the surfaces both occlusally and cervically to the line. The depth of retentive undercut is refined by a similar grinding process. Should there be a lack of sufficient undercut, additional porcelain should be applied and fired to create more bulge at the survey line.

The porcelain is cleaned ultrasonically, characterized, stained as required, and then glazed. The contours of both the porcelain and the metal surfaces are verified with the surveyor, and any needed refinements are accomplished. If further porcelain grinding is necessary, the surface must be reglazed. Rest seats are refined and remaining metal surfaces are polished in the usual manner in preparation for clinical try-in, adjustment, and cementation.

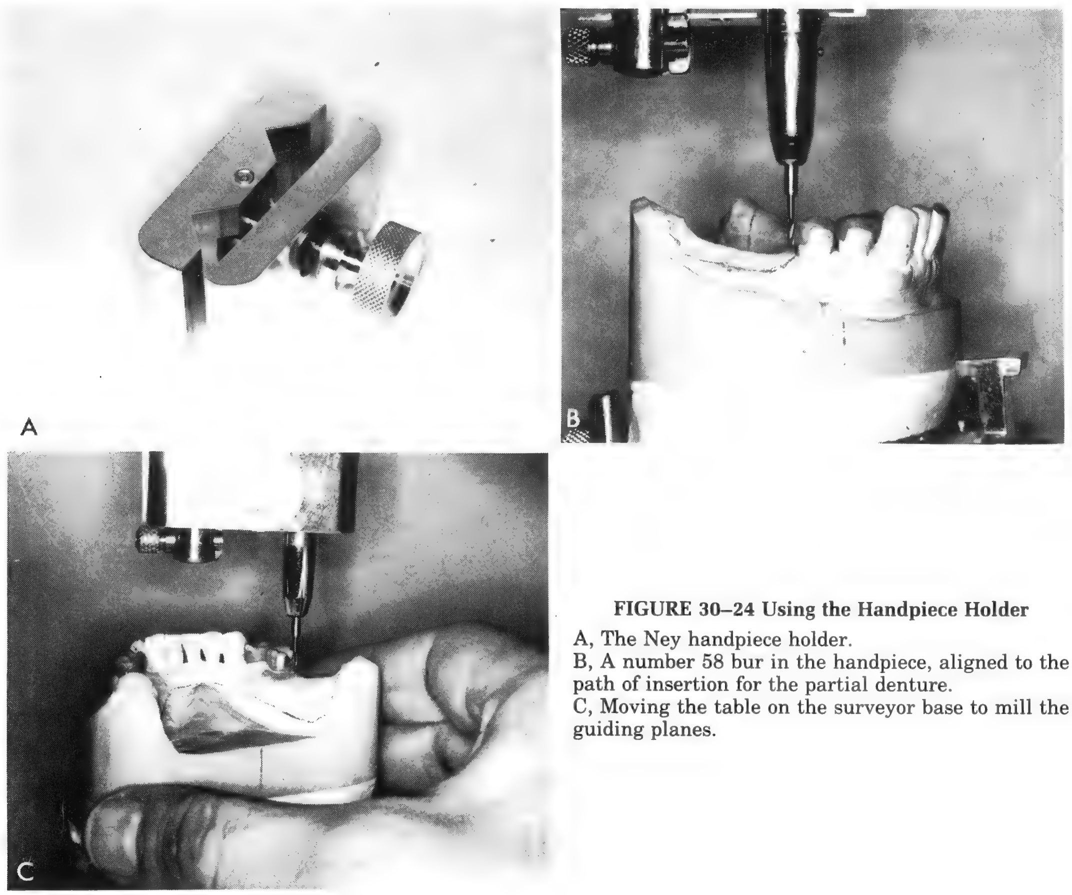


FIGURE 30–24 Using the Handpiece Holder

A, The Ney handpiece holder.
B, A number 58 bur in the handpiece, aligned to the path of insertion for the partial denture.
C, Moving the table on the surveyor base to mill the guiding planes.

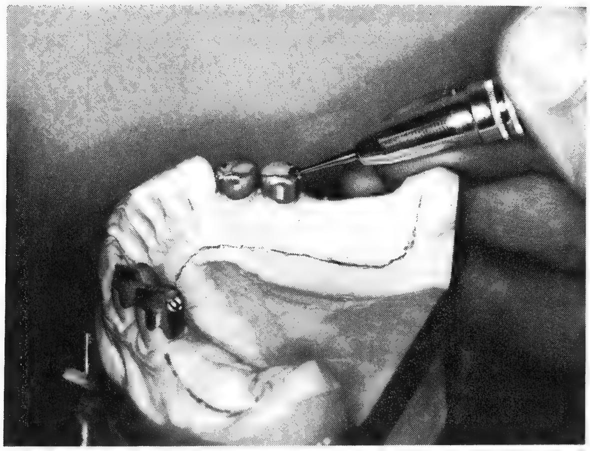


FIGURE 30–25 Using a round bur to finish a rest seat.

RESTORATIONS FOR INTRACORONAL ATTACHMENTS

Conditions exist in which the action or appearance of a partial denture can be improved by using an intracoronal means of retention rather than conventional extracoronal clasps.

TYPES OF INTRACORONAL ATTACHMENTS

Two basic classes of intracoronal attachments are used to retain removable partial dentures. One type is custom fabricated in the laboratory along with the other portions of the partial denture framework; the other is a manufactured key and keyway (precision attachment).

The discussion of the custom attachment in this chapter is limited to a type of custom attachment that produces a tapered dovetail-shaped vertical keyway in the proximal surface of an abutment restoration by molding the wax pattern around a special mandrel that is held in the dental surveyor. Metal is cast directly against the mandrel, which can then be removed from the restoration to yield a dovetailed rest in the casting. This rest is commonly used in conjunction with a cast lingual retentive clasp arm (Fig. 30–27).

The manufactured intracoronal attachment possesses a key and keyway, which has parallel walls and relies primarily on precise frictional fit for retention (Fig. 30–28). Adjustable retentive components are available with many attachments to provide additional retention should wear decrease available frictional retention. Examples of prefabricated attachments include the Ney-Chayes* and the Stern† attachments. These are made in several dimensions, although the largest sizes are not used as often, since many teeth cannot be reduced sufficiently to accommodate them.

The dovetailed rest is usually a little smaller than manufactured attachments and therefore requires less tooth reduction. Another advantage is the relative ease with which it may be fabricated. When it is used with a lingual retentive clasp arm, this attachment can satisfy esthetic requirements on teeth that are too small to accommodate manufactured attachments.

By virtue of eliminating facial clasp arms, the paramount advantage of intracoronal attachments is a better esthetic result (Fig. 30–29). This not only removes the visible clasp but also makes unnecessary the development of many of the crown alterations required for the conventional clasp. Therefore, when a tooth near the anterior portion of the mouth is chosen as an abutment for a removable partial denture, the intracoronal attachment may be the answer to satisfying the esthetic requirements of discriminating patients.

One of the disadvantages of an intracoronal attachment is the additional amount of tooth reduction required. To retain normal tooth form, which is a prime factor in maintaining gingival health, the intracoronal attachment should be contained within normal tooth contours. This cannot be done unless a rather large box is prepared in the proximal surface of the abutment.

Intracoronal attachments may be used in combination with clasps on the same removable partial denture. In

*The J. M. Ney Company, Bloomfield, CT 06002.
†APM-Sterngold, San Mateo, CA 94402.

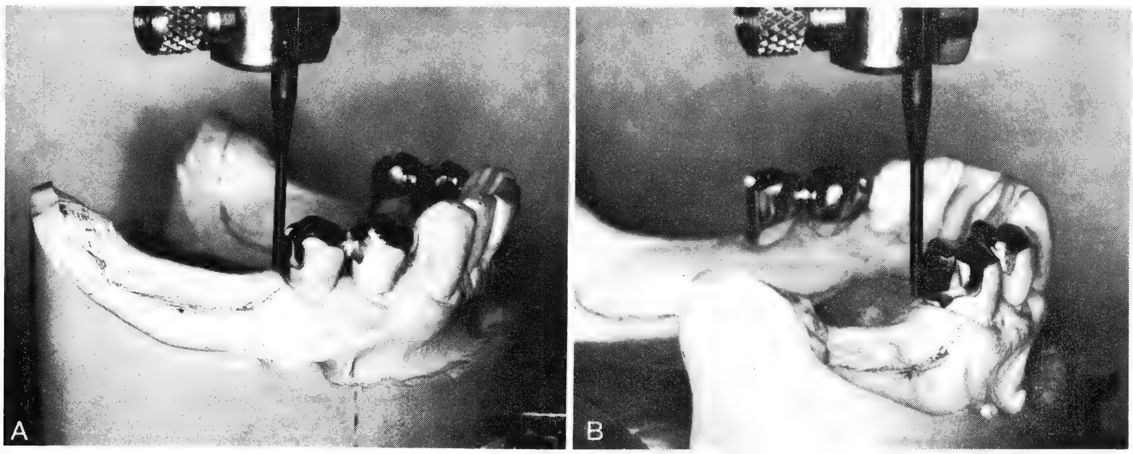


FIGURE 30–26
A, B, Rechecking contours after completion of polishing procedures.

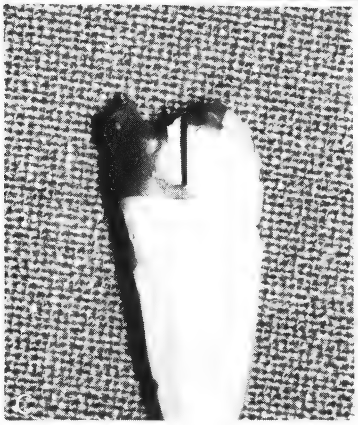


FIGURE 30–27 Intracoronal Attachment Removable Partial Denture with Tapered Dovetail Keyway

A, Occlusal view of prosthesis showing keyways seated in restorations and lingual retentive arms.
B, Ticon Mandrels, which are inserted into the wax pattern.
C, Tapered dovetail keyway formed in casting after mandrel has been removed.

a typical maxillary Kennedy Class III modification 1 design, precision attachments might be used in restorations on the canines and clasps on the second molars with an excellent esthetic effect as well as reduced complexity and cost of construction as compared with a prosthesis that uses intracoronal attachments in all the abutments (Fig. 30–30). Likewise, in a Kennedy Class IV situation the anterior abutment teeth can support intracoronal attachments while clasps are used posteriorly.

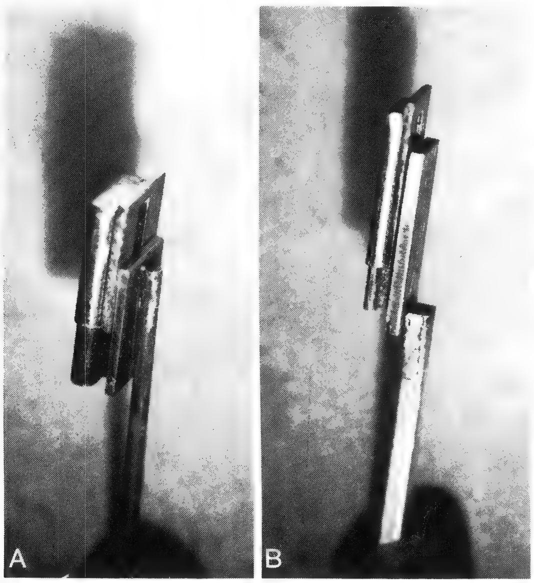


FIGURE 30–28 Precision Attachments

A, A Ney-Chayes intracoronal attachment with the key partially seated in the keyway.
B, A Stern G/A precision (intracoronal) attachment.
C, A maxillary removable partial denture with precision attachments.

C

Construction of Precision Attachment Partial Dentures

Prepreparation Procedures

A cast of the arch to be restored is surveyed to determine the best path of insertion for the prosthesis (Fig. 30–31). While it is kept in mind that each attachment must be recessed in its abutment tooth, a path is sought that causes the least tooth reduction and that therefore does not damage the pulpal tissue. When this path has been found, an attachment is placed in the surveyor and used to mark the location and dimensions of the box, which must be cut into the tooth (Fig. 30–32A, B, C).

The proximal box dimensions must be larger than those developed for conventional rest seats and should provide about 0.3 to 0.5 mm of space at the sides and the back of the attachment. A box with the following dimensions allows the attachment to be contained within normal tooth contours: 4 mm faciolingually, 4 mm occlusocervically, and 2 mm mesiodistally (Fig. 30–33). Box size can be slightly reduced when the smaller attachments are used. The box is cut into the cast with a number 557 bur with the handpiece holder maintaining the alignment in the surveyor (Fig. 30–32D). The attachment is then placed in the surveyor to verify that an adequately sized box has been produced (Fig. 30–32E, F).

Tooth Preparation

The cast with the cut recesses (Fig. 30–34A) is used to guide the depth and angle of the cuts made in the teeth. While an experienced operator can produce the proper box size, location, and angulation by visually comparing the tooth and the prepared cast, a resin or cast metal template that outlines the cuts is helpful for the beginner (Fig. 30–34B). The template is formed on the cast over the teeth, which have been diagnostically prepared to outline box size, location, and angulation. The template can be seated over a tooth and used as a guide during tooth preparation (Fig. 30–34C).

The proximal box to receive the attachment is cut first by seating the template over the tooth and using it to locate the box and determine its depth (Fig. 30–34D). The remainder of the crown preparation is then completed. Additional grooves and post holes can be placed where they are necessary to assure maximally retentive preparations. The intracoronal attachment can generate a very positive action on retainer castings to transmit strong tipping and torsional dislodging forces if there is movement of the prosthesis. A retainer lacking in length, parallel walls, and other retentive qualities may be loosened by these adverse forces.

FIGURE 30–29 Maxillary removable partial denture retained by clasps that are very conspicuous. Intracoronal attachments would have eliminated this obviously nonesthetic condition.

Retainer Castings

Full-contour patterns for the retainer castings are developed by the techniques delineated earlier. When the patterns have been made, the cast is transferred to the surveyor table, which has been adjusted to the selected path of insertion. A recess to accept the keyway portion of the attachment is carved in the proximal surface of each pattern. To facilitate cutting of this recess, the female portion of the attachment is placed in the surveyor and used as an outline (Fig. 30–35A) for carving a niche (Fig. 30–35B) in the pattern into which the attachment can fit closely but without friction.

The female portion of the attachment is held into the pattern recess while the surveyor and mandrel holder assure proper alignment. Wax is flowed between the attachment and existing pattern and allowed to cool with the surveying mandrel in position (Fig. 30–35C). The mandrel is then removed, and a smooth transition

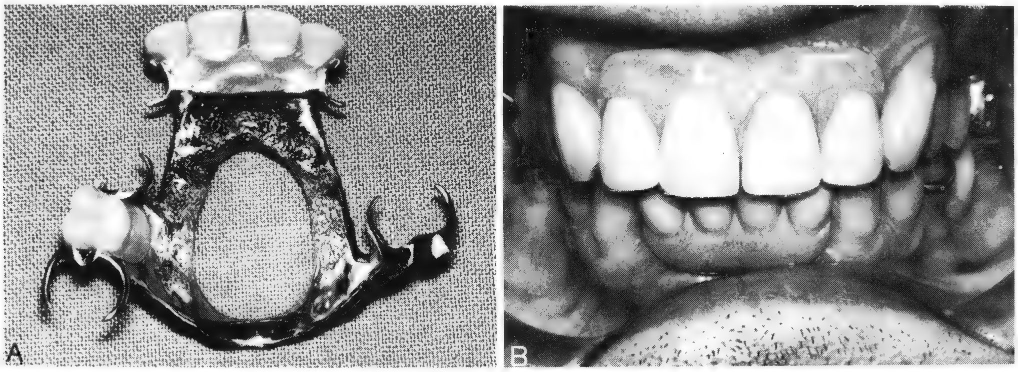


FIGURE 30–30
A, B, Kennedy Class III modification 1 removable partial denture with intracoronal attachments anteriorly and circumferential clasps posteriorly.

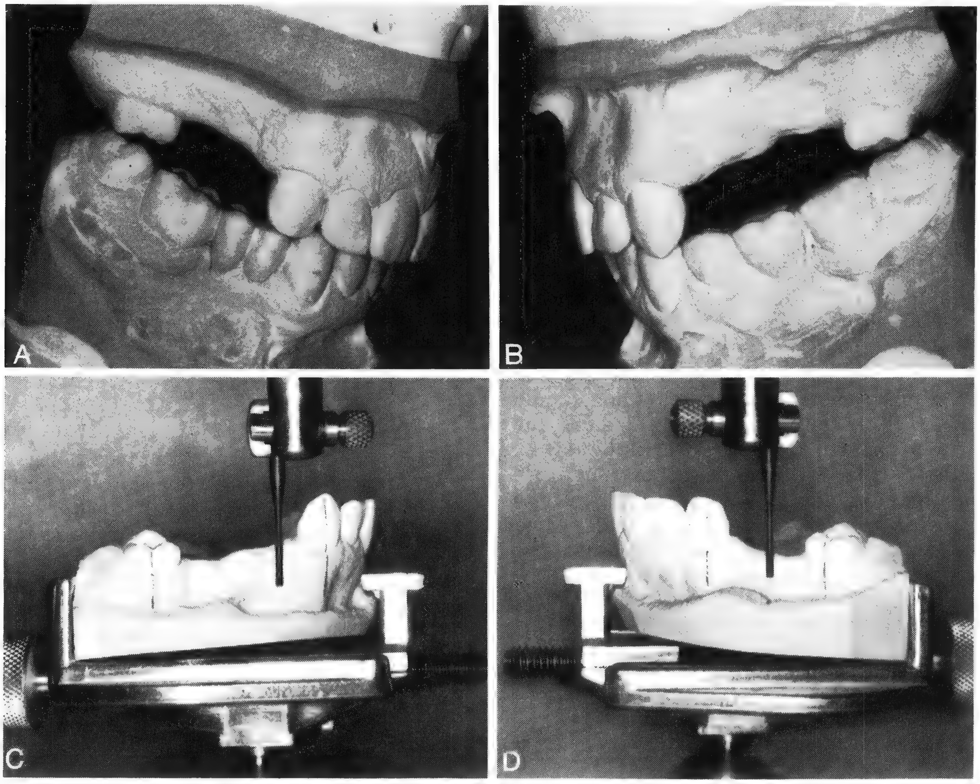


FIGURE 30–31

A, B, Articulated casts depicting a Kennedy Class III modification 1 situation, which is an indication for a precision attachment partial denture.
C, D, Using the dental surveyor to select the path of insertion. Anterior teeth are favored wherever possible.

is carved between the attachment and the wax pattern. The pattern is returned to the die for marginal readaptation.

When a precision attachment is to be used in a metal-ceramic restoration, the keyway must be able to withstand elevated temperatures. A special high-fusing attachment is therefore recommended.

Prior to investing, the attachment recess is partially filled with a thin mix of investment, and a carbon rod that is supplied with the attachment is inserted into the recess. The rod must project well above the attachment. When this investment sets, the sprue former is attached, and the pattern is invested. Investment engages the carbon rod and holds the attachment in its proper position when the wax pattern is burned out and the molten alloy enters the mold.

The casting is removed from the investment, the carbon rod and investment are removed from the recess, and the casting is cleaned as usual. The restorations are returned to the working cast on the survey table, and the alignment is rechecked by inserting the paralleling mandrel into each keyway. Parallelism may also be verified by inserting mandrels in all attachments without the use of the surveyor and checking the relationships by eye. When the observer sights past one mandrel shank at the others, all shanks should appear to be in perfect alignment. Once parallelism has been confirmed, the attachments are trimmed flush with the occlusal or lingual surfaces and the castings are polished (Fig. 30–36).

Alternative Soldering Technique

An alternative technique involves casting the crown around a high-fusing metal tray (available for the Ney-Chayes attachment only) located proximally into which the female portion of the attachment can subsequently be soldered. The tray yields a smooth recess with just the amount of room needed for the solder to be used to join the keyway with the retainer casting.

RESTORATIONS FOR PARTIAL DENTURES WITH DOVETAILED RESTS

Many of the clinical and technical procedures by which a tapered key and keyway are fabricated are essentially the same as those for prefabricated attachments. The major differences are: (1) the keyway is formed in the wax pattern for the abutment restoration; (2) the key or rest, ordinarily with a lingual retentive arm, likewise is constructed in the laboratory; and (3) the box prepared in the tooth can be smaller, with dimensions of 2 mm faciolingually, 3 mm occlusocervically, and 2 mm mesiodistally (Fig. 30–37).

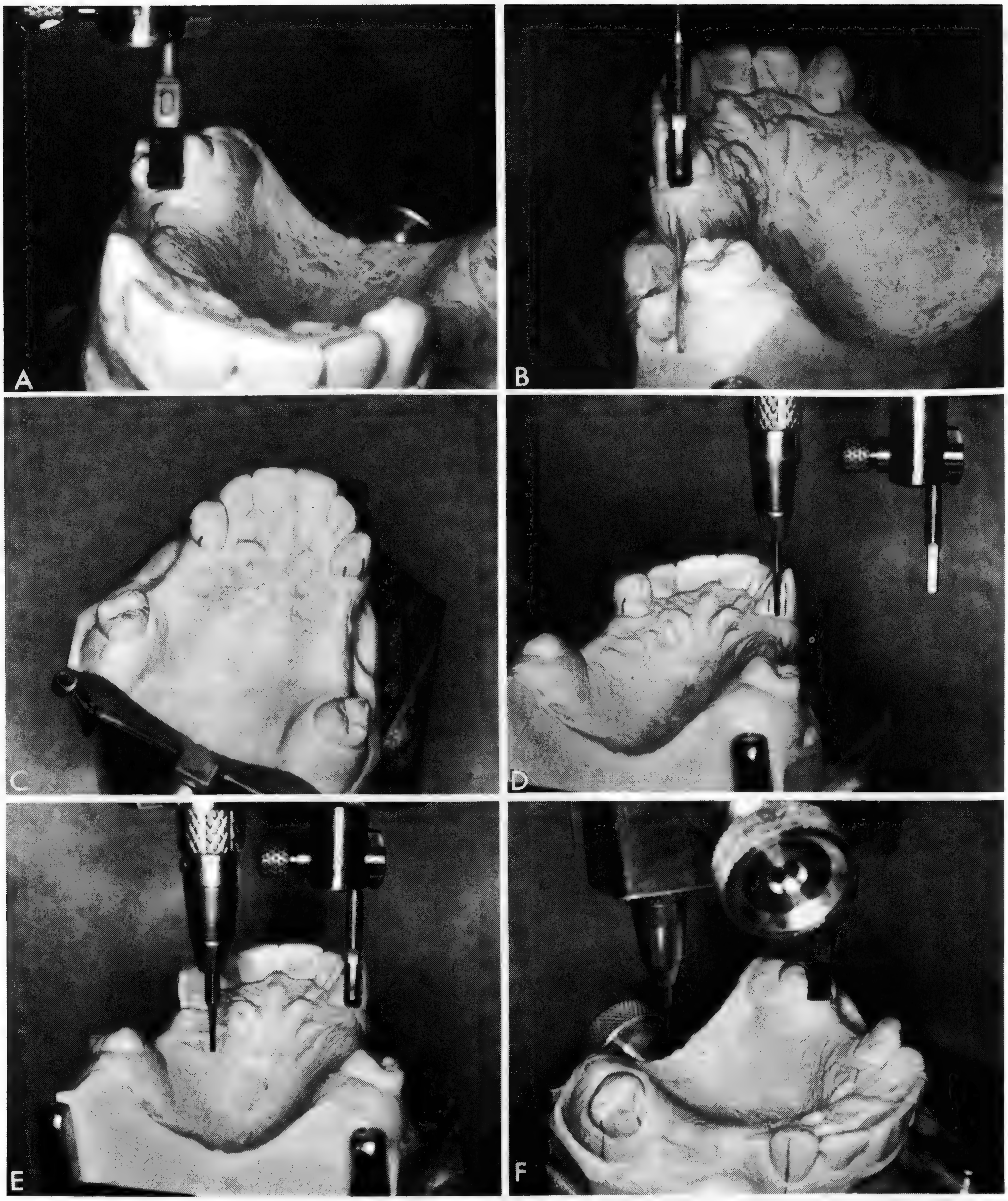


FIGURE 30–32 Preparation of Proximal Boxes on Cast

A, B, Attachments held in the surveyor and positioned against the proximal surfaces of the teeth to receive intracoronal attachments.
C, Proximal surfaces marked to indicate the location of boxes.
D, Cutting box in stone tooth with a handpiece holder.
E, F, Boxes cut sufficiently large to contain attachments.

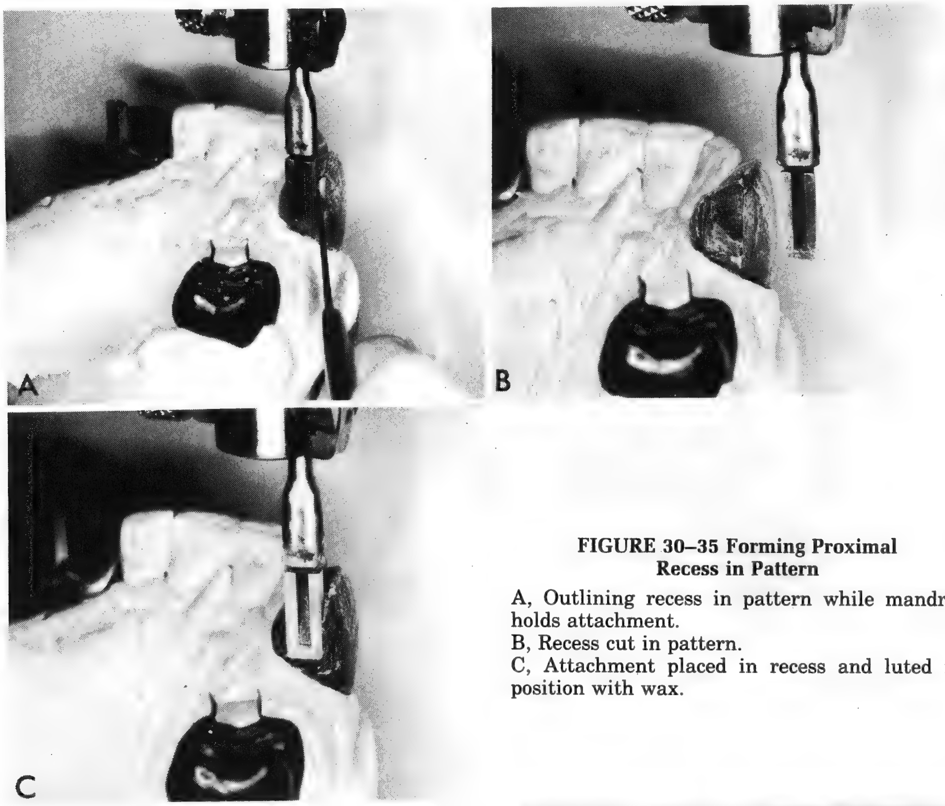


FIGURE 30–35 Forming Proximal Recess in Pattern

A, Outlining recess in pattern while mandrel holds attachment.
B, Recess cut in pattern.
C, Attachment placed in recess and luted in position with wax.

FIGURE 30–36 Attachments shortened and restorations polished.

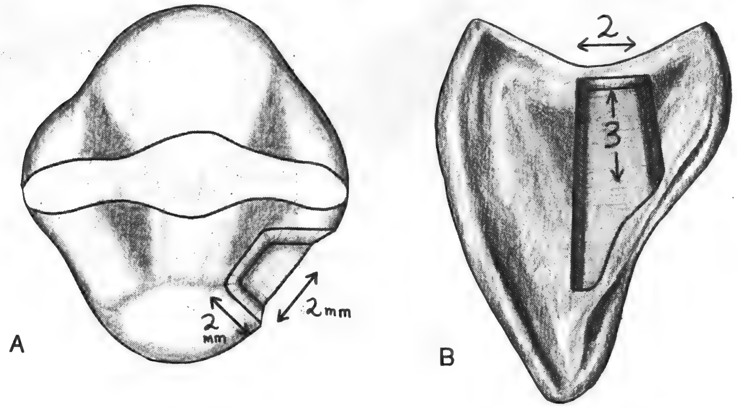


FIGURE 30–37

A, B, Dimensions of proximal box required for dovetailed rest.

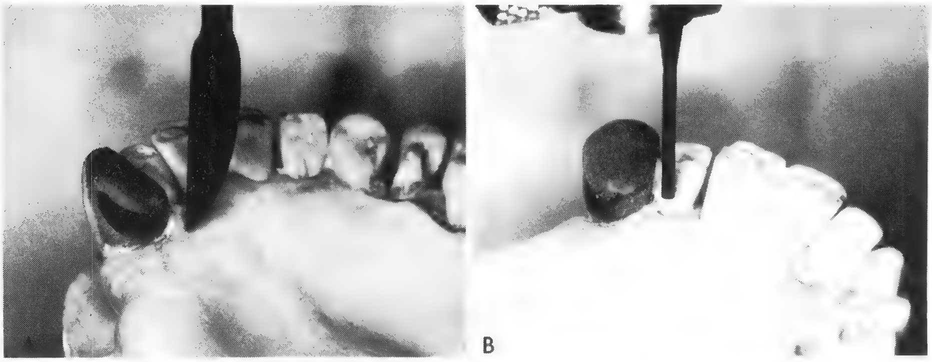


FIGURE 30–38 Preparation of Wax Pattern

A, Proximal guiding plane formed.
B, Lingual height of contour established for a cast retentive clasp.

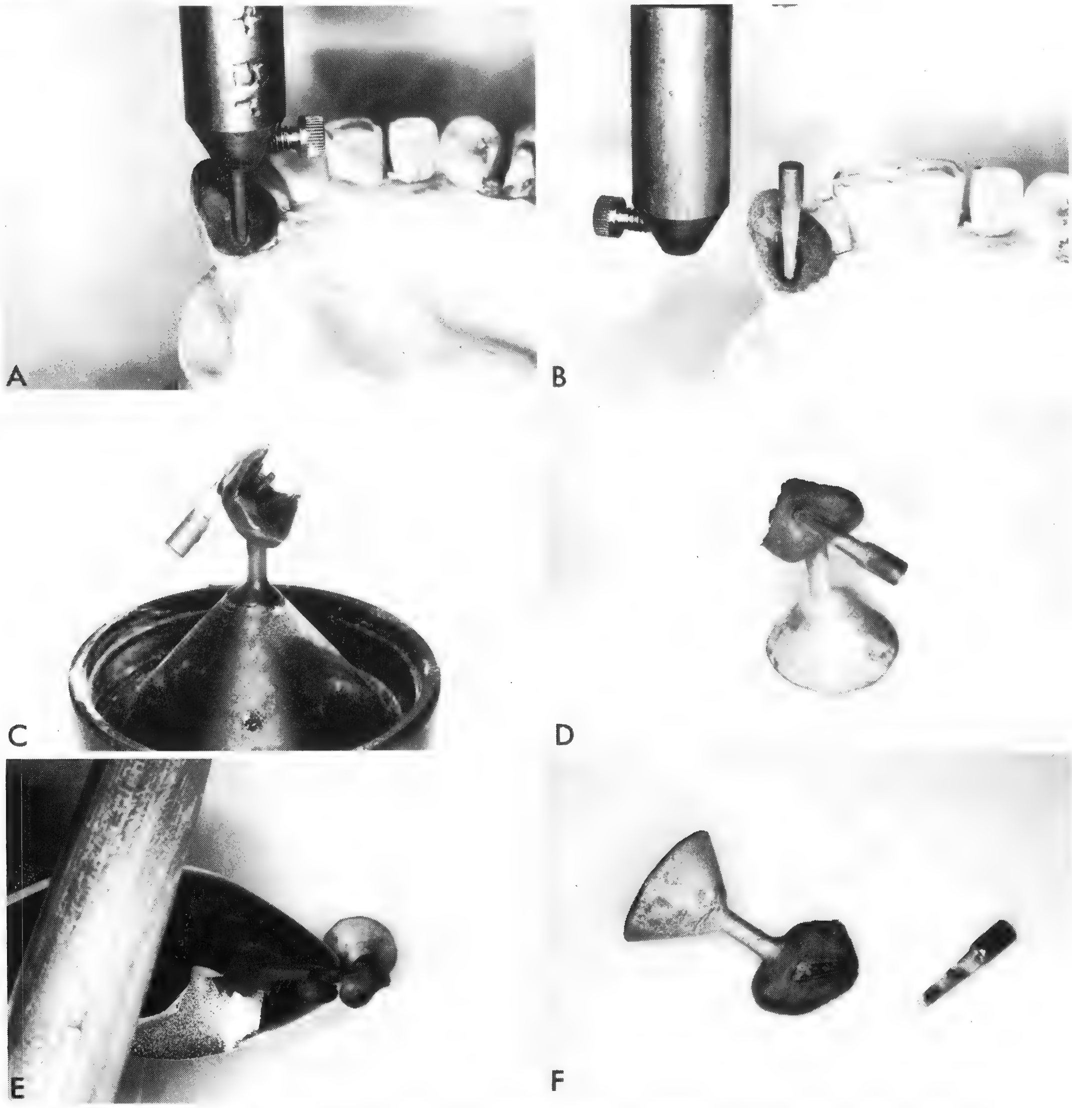


FIGURE 30–39 Adapting the Pattern to a Rest-Forming Mandrel and Producing the Casting

A, Ticon mandrel in position in pattern recess.
B, Mandrel luted.
C, Pattern ready for investing.
D, Casting divested.
E, Removing the mandrel from the casting.
F, Mandrel removed. This is done before pickling to prevent contamination of the pickling agent by base metal from the mandrel.

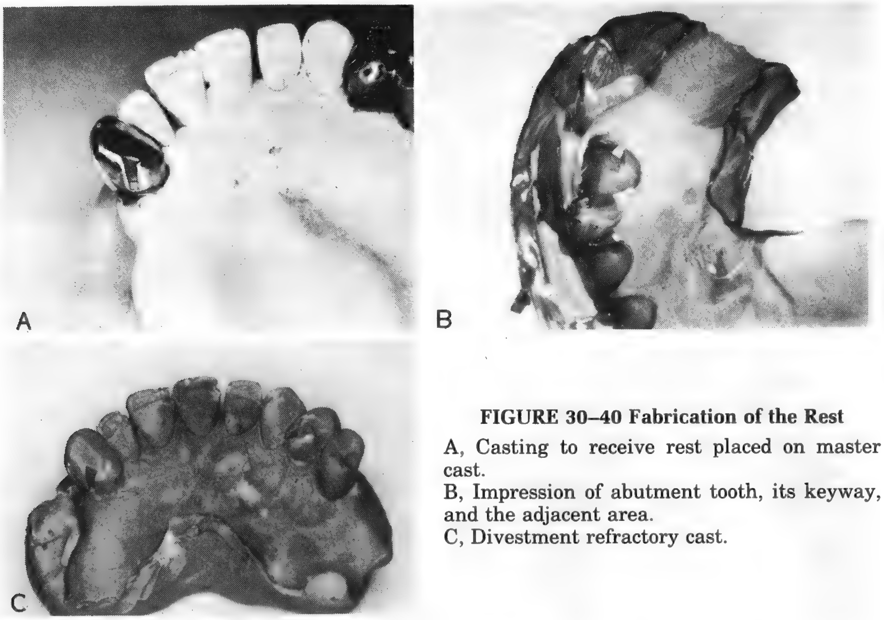


FIGURE 30–40 Fabrication of the Rest

A, Casting to receive rest placed on master cast.
B, Impression of abutment tooth, its keyway, and the adjacent area.
C, Divestment refractory cast.

Fabricating the Rest

The best alignment and fit of a dovetail rest can be attained if it is constructed separately from the remainder of the framework and joined by soldering. If it is to be used without the retentive arm, it can be waxed directly in the restoration on the master cast. The pattern is removed, invested, and cast.

If a retentive arm is to be included, a duplication in investment must be made both of the tooth that is to receive the rest and of the adjacent ridge area (Fig. 30–40). A rubber impression is obtained (Fig. 30–40B)

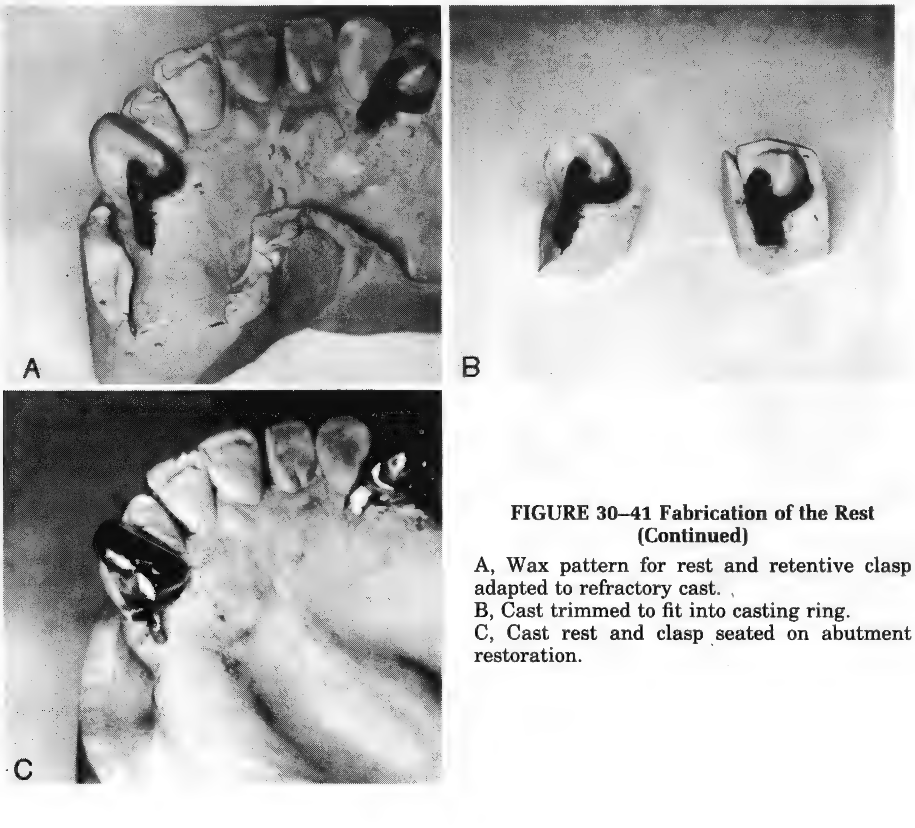


FIGURE 30–41 Fabrication of the Rest (Continued)

A, Wax pattern for rest and retentive clasp adapted to refractory cast.
B, Cast trimmed to fit into casting ring.
C, Cast rest and clasp seated on abutment restoration.

and poured with Divestment* (Fig. 30–40C), a material that is used to form a die that can be invested together with its pattern. If the attachment minor connector is to be attached to a portion of the framework that is to retain an acrylic resin base, ample relief should be provided over the soft tissue portion of the cast prior to making this impression.

Wax patterns for the rest, the retentive arm, and the minor connector are formed on the Divestment cast (Fig. 30–41A, B). The minor connector should extend at least 5 mm away from the abutment tooth to provide sufficient area for soldering. After the rest has been cast, it is finished, polished, and fitted to the abutment casting (Fig. 30–41C). It is then soldered to the removable partial denture framework (Fig. 30–42).

*Whip-Mix Corporation, Louisville, KY 40217.

RESTORATIONS FOR OVERDENTURES

Additional support and retention for a complete or removable partial denture can be obtained by overlaying

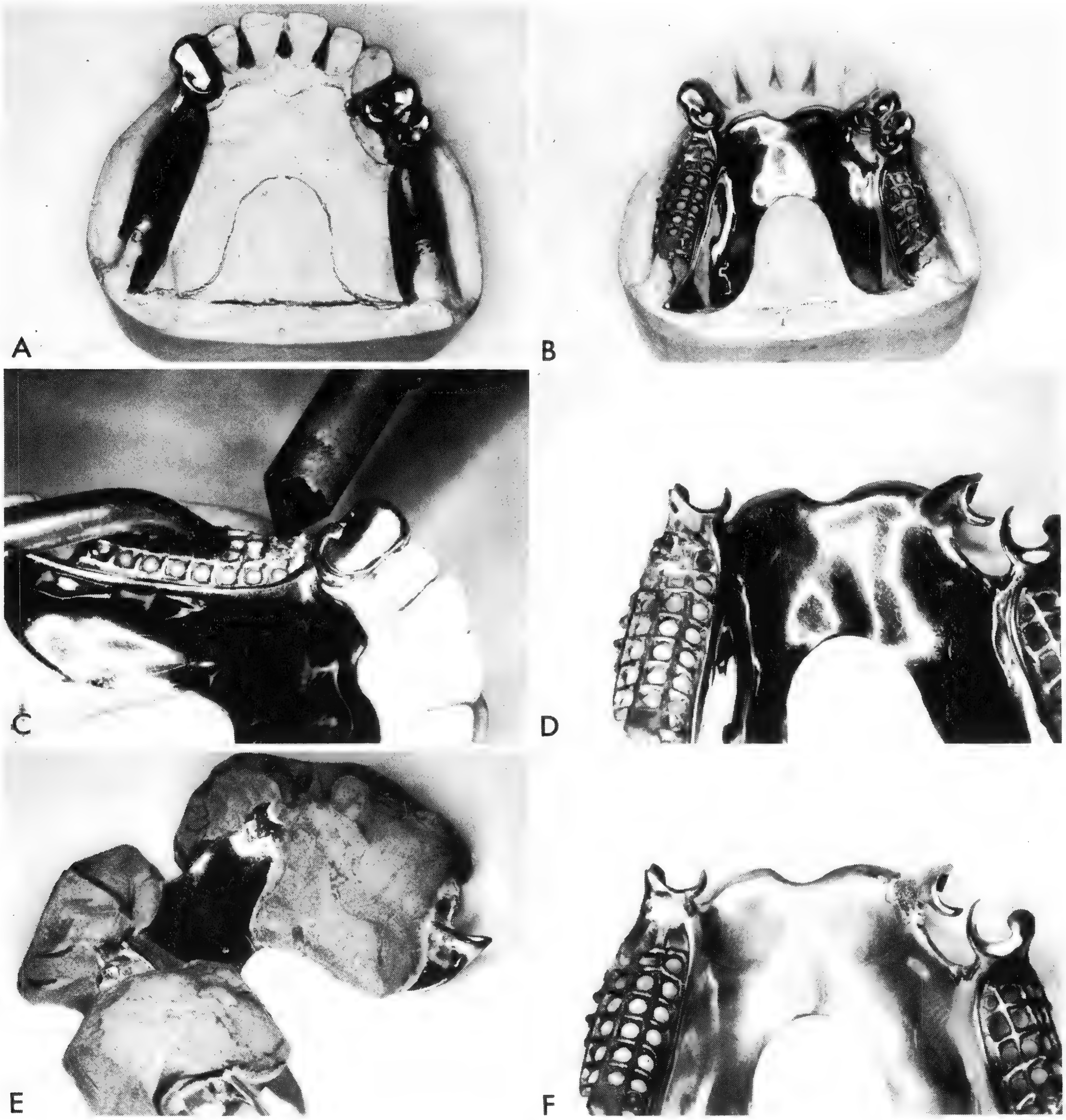


FIGURE 30–42 Soldering the Attachment Assembly to the Framework

A, Master cast waxed for duplication.
B, Framework casting on master cast.
C, Using electrosoldering to tack the assembly to the framework.
D, Joints waxed before investing the framework for final soldering.
E, Framework invested for soldering.
F, Soldering completed.

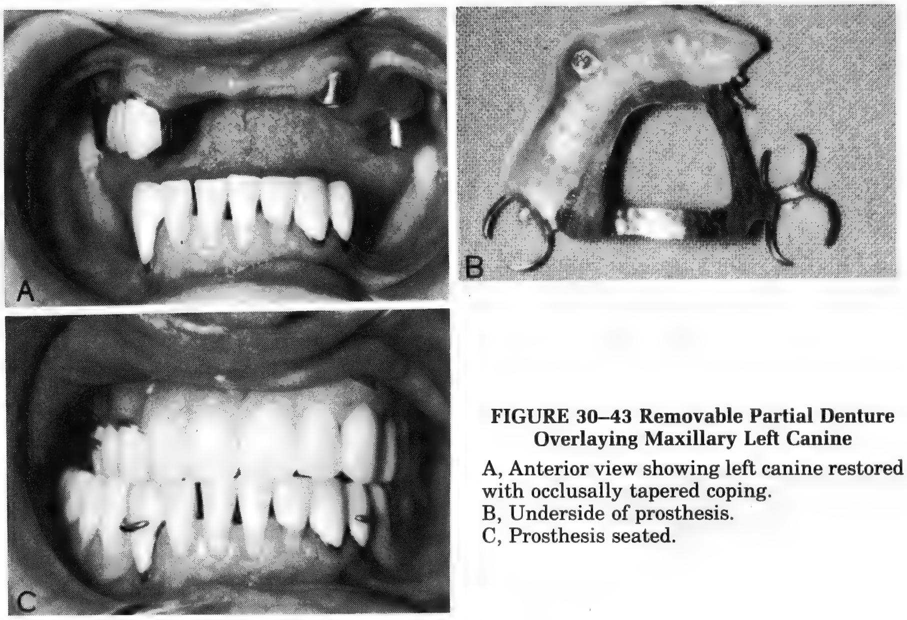


FIGURE 30–43 Removable Partial Denture Overlaying Maxillary Left Canine

A, Anterior view showing left canine restored with occlusally tapered coping.
B, Underside of prosthesis.
C, Prosthesis seated.

natural teeth that have been restored so they possess an occlusally tapered form that allows coverage by the denture. The restorations can also include mechanically retentive attachments* to aid retention of the prosthesis (Figs. 30–43 and 30–44).

*Ceka Attachment, J. F. Jelenko Company, Armonk, NY 10504.

Tooth Preparation

Generally, endodontic treatment is required prior to tooth preparation so that the teeth can be shortened significantly. The reduction in height is needed so that leverage brought to bear on the teeth is reduced, the desired tapered form is established, and space is created for the overlying denture and prosthetic teeth.

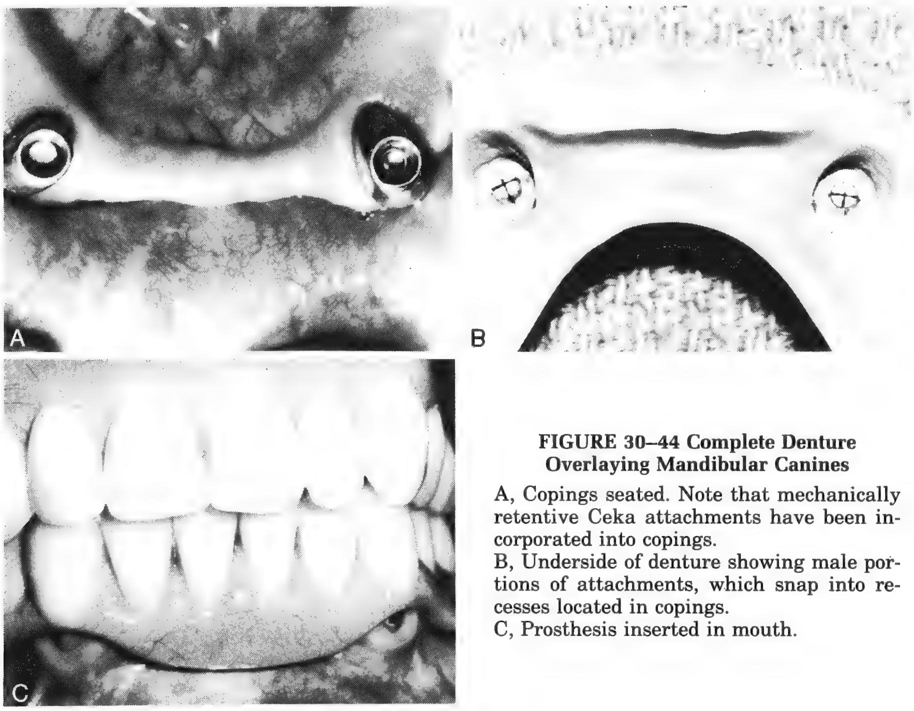


FIGURE 30–44 Complete Denture Overlaying Mandibular Canines

A, Copings seated. Note that mechanically retentive Ceka attachments have been incorporated into copings.
B, Underside of denture showing male portions of attachments, which snap into recesses located in copings.
C, Prosthesis inserted in mouth.

FIGURE 30–45 Full veneer preparations completed on endodontically treated mandibular teeth.

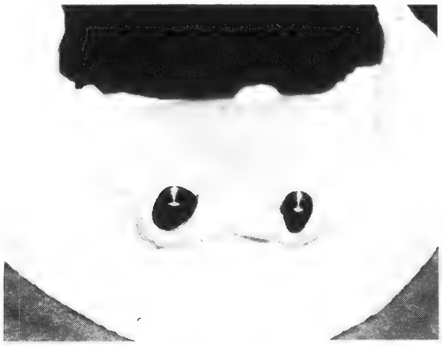


FIGURE 30–46 Ceka attachments positioned in wax patterns.

The preparation procedure involves first shortening of the tooth to the required height and then completion of a full veneer preparation of maximal length on remaining tooth structure (Fig. 30–45). A post in the root canal is often required in order to achieve adequate retention. If the remaining root length allows only a short post preparation, auxiliary grooves and pinholes can be used to augment retention. If a retentive attachment is being used, the occlusal aspect of the post preparation should be increased in diameter to provide space for the attachment and sufficient surrounding metal for rigidity. An impression is then obtained of the prepared teeth, post spaces, and edentulous ridge.

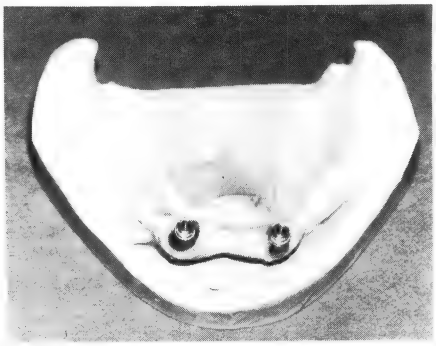


FIGURE 30–47 Finished casting seated on working cast.

Wax Pattern Formation

Wax is adapted to the prepared root canal and any other auxiliary retentive features. When an attachment is being used, it is positioned by using a surveying mandrel for alignment with other attachments and the edentulous ridge and luted to the initial post pattern (Fig. 30–46). The dome-shaped coping form is then completed, and the pattern is invested, cast, finished, and cemented as usual (Fig. 30–47).

31

Resin-Bonded Prostheses

In the presence of relatively intact abutment teeth, new materials and techniques allow placement of metal-ceramic prostheses that are bonded to the teeth with resin, in much the same way as are acid-etched composite restorations. Tooth preparations are of minimal depth and terminate in enamel, which can be more effectively etched and bonded to resin than dentin. Since these restorations require only minimal tooth preparation, they can be used without pulpal damage regardless of pulp size. Also, the clinical and laboratory time is generally less, so the procedure is less expensive for the patient. Initial data indicate that these prostheses can be mechanically and esthetically successful for many years. Their success, as with any prosthesis, depends on well-fitting castings and careful adherence to technical procedures.

Several different design variations have been developed for the metal substructure, varying primarily in the manner in which the resin mechanically interlocks with the casting. Early designs employed metal castings that were perforated lingually so the resin could encompass the casting.

Recently, other variations in mechanical retention design have been developed. One frequently used technique employs a base metal casting that develops microscopic retentive areas when the metal surface that is to contact the prepared tooth is electrolytically acid-etched. This technique is not suitable for use with gold-containing alloys, since these alloys cannot be etched in this manner. Other designs employ macroscopic retention by incorporating a small retentive meshwork into the undersurface of the wax pattern where it contacts the lingual surface of the abutment teeth. Also, water-soluble salt crystals may be incorporated into the undersurface of the wax pattern and later dissolved out of the wax with water just prior to investing. The resulting casting has voids into which the resin can interlock. These macroscopic retention techniques can be employed with any of the base metal or noble metal-ceramic alloys.

TOOTH PREPARATION

Tooth reduction involves only nonvisible portions of the proximal and lingual surfaces. Since this reduction terminates in enamel, anesthesia is not usually required.

The preparation should include a small but definite peripheral finish line, which is created with the tip of a round-end diamond instrument. The proximal surfaces of abutment teeth are slightly reduced to remove interproximal undercuts and to provide parallel surfaces for maximal retention. One or two shallow proximal grooves are placed in each proximal surface to enhance the resistance and retention form. The lingual surface is reduced for occlusal clearance sufficient to create adequate casting rigidity. Generally the minimal acceptable space for short-span (three-unit) prostheses with normal occlusal forces is 0.3 mm. Slightly greater thickness (0.5 mm) is advantageous for longer spans or heavier than normal occlusal forces. When there is existing occlusal clearance, it may not be necessary to reduce the abutment teeth lingually, whereas reduction of opposing teeth may be necessary when occlusal contact exists between the abutment teeth and opposing teeth over broad areas of the lingual surface.

The placement of one or two shallow ledges that extend across the reduced lingual surfaces increases the casting rigidity and, along with the proximal grooves, aids in orienting the casting during insertion and cementation (Fig. 31–1).

FABRICATING PROCEDURES

The laboratory fabrication procedures vary depending on whether microscopic or macroscopic retention is used.

MICROSCOPIC RETENTION

The cast is lubricated and either resin* or wax is adapted to the prepared lingual and proximal surfaces of the abutment teeth (Fig. 31–2A). To increase rigidity, a bar of resin is formed between the two abutment retainers and a pontic wax pattern is formed around it (Fig. 31–2B). The pontic wax pattern is then carved back to create space for porcelain, and the retainer margins are refined with wax as needed (Fig. 31–2C, D). A ten-gauge sprue former is attached to the incisal edge of the pontic and smaller 14-gauge sprue formers

*Duralay, Reliance Dental Manufacturing Company, Worth, IL 60482.

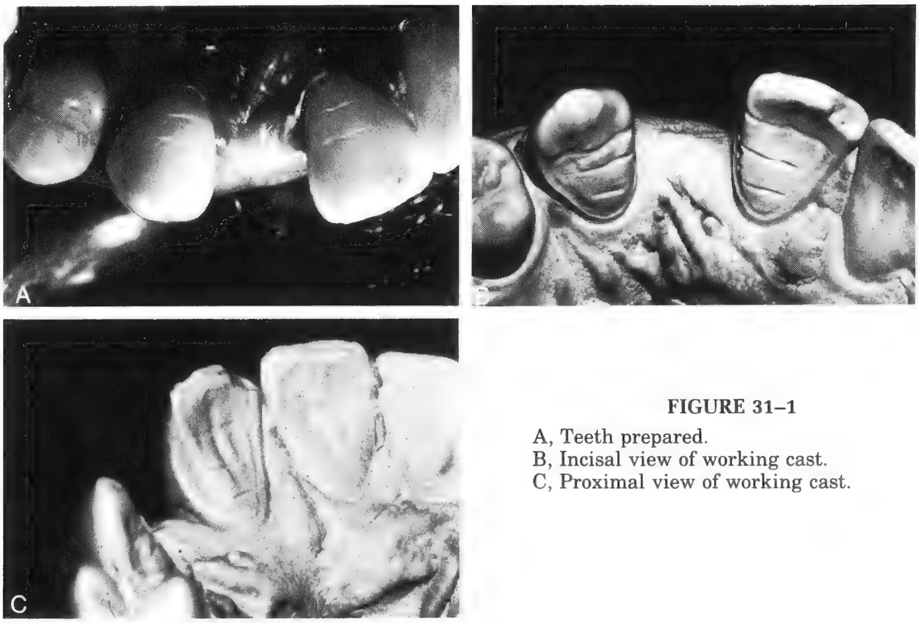


FIGURE 31–1
A, Teeth prepared.
B, Incisal view of working cast.
C, Proximal view of working cast.

are attached to each retainer pattern. The pattern is carefully removed from the cast as one unit and invested in a carbon-free phosphate-bonded investment, employing the usual procedures for a base metal alloy. Alternately, a special refractory cast material* can be poured directly into an impression of the prepared teeth, and

*DVP Investment, Whip-Mix Corporation, Louisville, KY 40217.

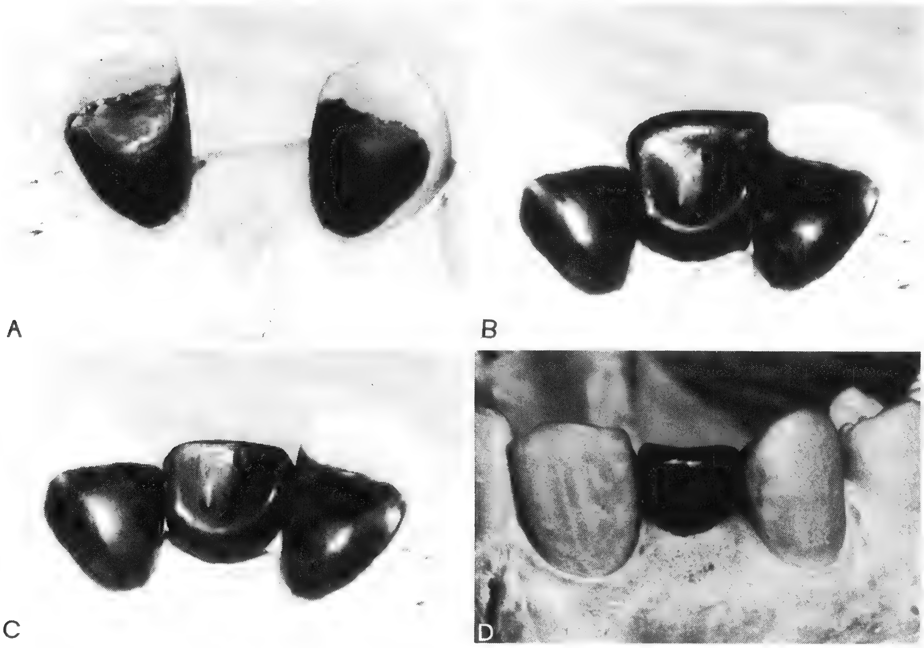


FIGURE 31–2
A, Retainer patterns formed on cast.
B, Pontic formed.
C, D, Pontic carved back to create space for porcelain.

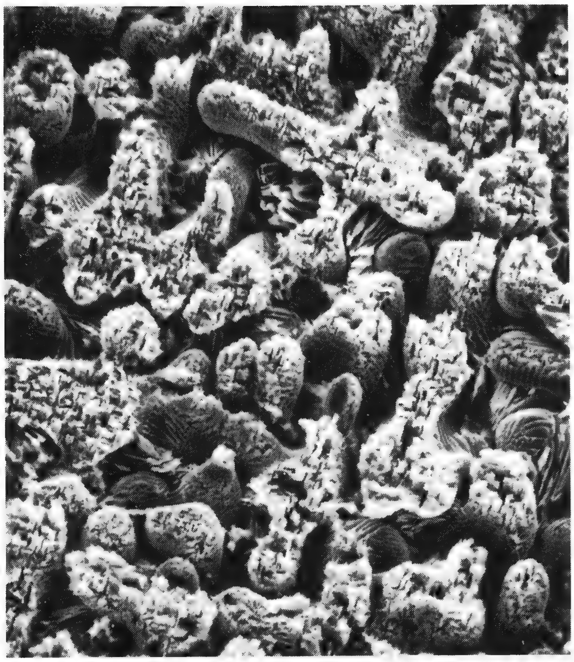


FIGURE 31–3 Scanning electron micrograph of etched base metal. Magnification × 1000. (Courtesy of B. K. Moore.)

the framework can be waxed directly to the cast without removal of the patterns. The refractory cast is sectioned so that only the abutment teeth and edentulous ridge section remain. Sprue formers are attached to the patterns and, with this section of the cast, are invested in the same refractory material.

The casting is made and finished, and porcelain is applied and glazed in the usual manner. The prosthesis is then electrolytically etched to provide mechanical retention (Fig. 31–3).

Tooth contacting surfaces of the casting are cleaned by air abrasion with 50-μm aluminous oxide, and the casting is attached to an electrode with sticky wax. All porcelain should be covered with wax as well as all metal surfaces not in contact with the prepared teeth. Sulfuric or nitric acid is used to electrolytically etch the

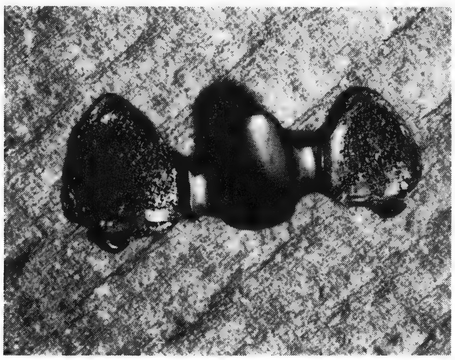


FIGURE 31–4 Casting in which a meshwork was used to provide retention for the resin.

FIGURE 31–5 Salt crystals applied to working cast.

casting, depending on the type of base metal alloy being used. Generally, nickel-chromium-beryllium alloys are etched with sulfuric acid, whereas nitric acid is used on nickel-chromium and cobalt-chromium alloys. However, variations exist with different alloy brands. A textbook dealing specifically with this procedure should be consulted for recommendations as to the type of acid, concentration, and the time and current density to be used for a particular brand of alloy. Special etching units are available commercially for this purpose. Following the etching procedure, the restoration is ultrasonically cleaned in 18 per cent hydrochloric acid for 10 minutes.

The prosthesis is immersed in cold water so that the wax becomes brittle and can be removed easily. The

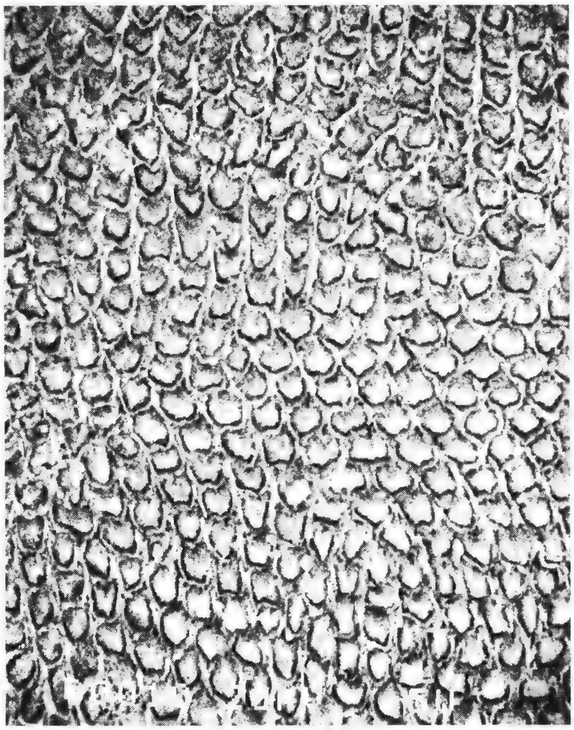


FIGURE 31–6 Scanning electron micrograph of etched enamel. Magnification × 1000. (Courtesy of B.K. Moore.)

prosthesis is then dried so that the quality of the etched surface can be evaluated.

Proper metal treatment must be verified by microscopic examination of the casting surface using a minimal magnification of × 60. If three-dimensional mechanical retention is not obvious, the casting must be re-etched.

Macroscopic Rentention

When a retentive meshwork is used, a water-soluble adhesive is first applied to the cast in areas in which the mesh is to be applied. The mesh is cut to size and then pressed into contact with the adhesive. Areas surrounding the mesh are coated with die lubricant, and the wax pattern is formed over and around the mesh. The usual pontic form is developed. The completed pattern is immersed in water to soften the adhesive and to release the wax from the cast. The cast is then relubricated, the marginal wax is reflowed, and the margins are finalized. Sprue formers are attached, as described for the microscopic retention technique, and the patterns are invested and cast in the usual manner (Fig. 31–4). Porcelain is applied to the pontic, and the castings are finished.

As an alternative macroscopic technique, water-soluble salt crystals can be applied to the cast in place of the preformed meshwork (Fig. 31–5), as previously described, with the remainder of the procedures being the same.

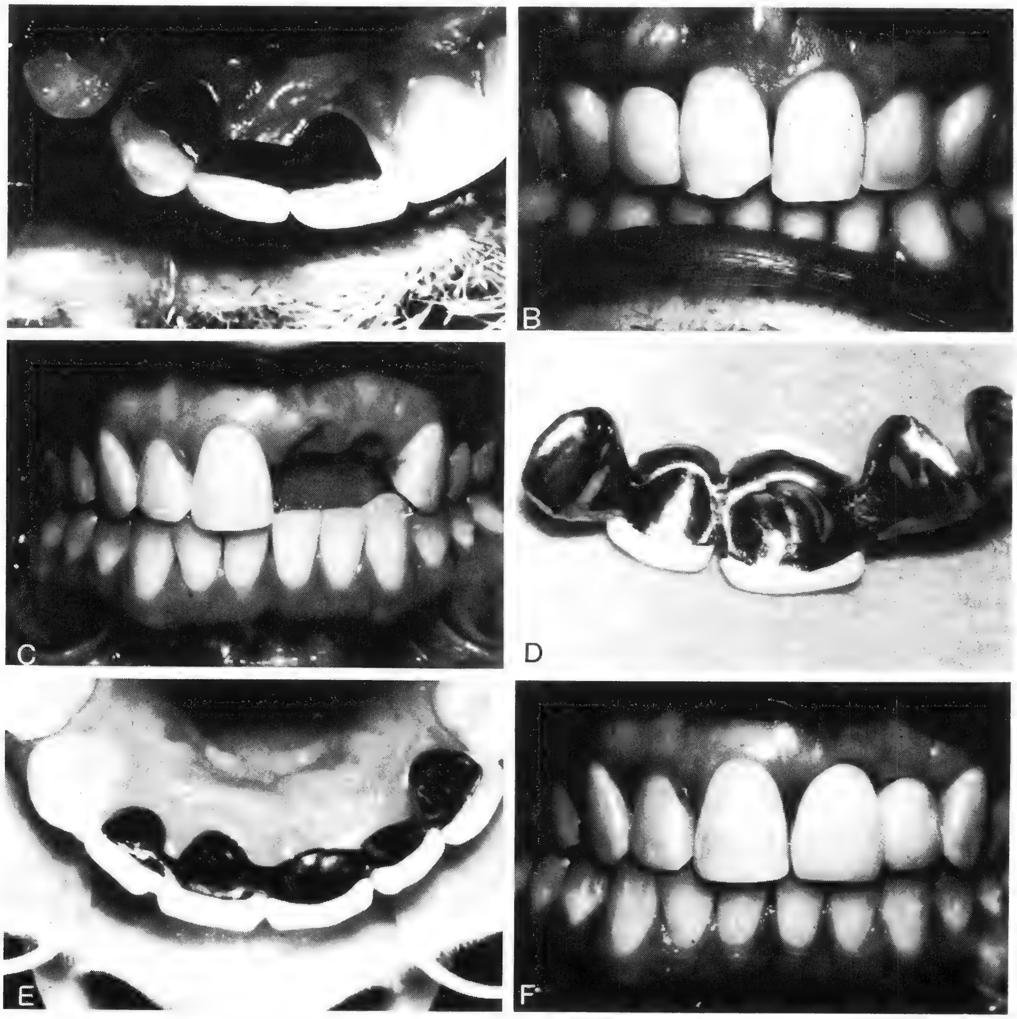


FIGURE 31–7

A, B, Cemented restoration shown in Figures 31–1 and 31–2.
C, Edentulous area prior to insertion of five-unit resin-retained prosthesis.
D, Finished prosthesis.
E, Mirror view of prosthesis.
F, Facial view.

CLINICAL INSERTION

A rubber dam is used to isolate the abutment teeth. The teeth are dried and etched in the same manner as for tooth-colored restorative resins (Fig. 31–6). Resins specially designed for cementation of these types of prostheses are employed. The BIS-GMA system is generally employed as the luting cement, with the addition of up to 65 per cent filler such as barium glasses. The resulting composite resin provides the added strength required to maintain a bond under masticatory stress.

The prosthesis should be ultrasonically cleaned just prior to cementation to remove debris that may have accumulated in the retentive areas and to ensure proper interlocking of the metal and resin.

A bonding resin is first applied to the casting and tooth as directed by the manufacturer. The composite resin is next applied to the prosthesis, which then is fully seated. Any excess material should be removed before it hardens, since removal may be extremely difficult interproximally after setting. The restoration should be held motionless until complete hardening of the resin has occurred. After polymerization, any remaining resin is removed from the surface of the restoration and teeth (Fig. 31–7).

When very translucent teeth are encountered, the use of an opaque resin can reduce the effect of the dark metal showing through the tooth and detracting from the esthetic result. The visible metal can also be cut away from behind a translucent incisal edge so long as adequate surface area for bonding remains.

32

Occlusion

George W. Simpson, D.D.S.

In order to more completely understand the complex function of the gnathic system, an attempt must be made to identify the anatomic and physical principles responsible for this function. These factors are important because of their influence on the recusping of teeth and the perfection of the occlusion of teeth.

The morphologic patterns of the occlusal surfaces and the lingual contours of the maxillary anterior teeth are related to the patterns of mandibular movement. An evaluation of the occlusion should be made to learn how well tooth positions and contours are coordinated with these condylar-controlled mandibular movements. This evaluation should include a complete analysis of jaw movements and occlusal relations of the teeth, both clinically and with casts mounted on a suitable articulating instrument. The knowledge and experience gained by definitive measurements of jaw movement and an examination of the occlusion with the aid of casts mounted on a fully adjustable articulator best prepare the operator to diagnose tooth relations and to prescribe treatment.

DEFINITIONS

Occlusion is the contact of the opposing surfaces of the teeth of the two jaws.

Centric relation is the untranslated hinge position of the mandible in its relation to the maxilla.

Centric occlusion is the occlusion of the teeth as the mandible closes in centric relation. It is a reference position from which all other horizontal positions are eccentric.

Maximal intercuspation is the most closed complete interdigitation of mandibular and maxillary teeth irrespective of condyle centricity.

Disclusion is the term used to describe the contacting of only designated groups of teeth in order to disallow any contacting of other groups of teeth. Anterior disclusion is the term that is most commonly used to describe the contacting of anterior teeth to prevent the occlusion of the posterior teeth during eccentric closures of the mandible.

During a lateral movement of the mandible, the *orbiting* (nonworking) *condyle* revolves in an orbit around the rotational center of the opposite *rotating* (working) *condyle*. During a right lateral movement of the mandible, the right condyle is the rotating condyle, and the left condyle is the orbiting condyle. During a left lateral movement, the left condyle is the rotating condyle and the right condyle is the orbiting condyle (Fig. 32–1).

Protrusion is a forward movement of the mandible.

Retrusion is a backward movement of the mandible.

Transtrusion refers to the total lateral translation or side shift of the mandible (Fig. 32–1).

Mediotrusion describes the movement of the orbiting or nonworking condyle toward the midline of the head (Fig. 32–1).

Laterotrusion describes the movement of the rotating or working condyle as it moves laterally away from the midline (Fig. 32–1).

Surtrusion is the upward movement of the working or rotating condyle from its centric relation position.

Detrusion is the downward movement of either condyle from its centric relation position.

The *hinge axis* is an imaginary line connecting the rotational center of one condyle with the rotational center of the opposite condyle and around which the mandible makes opening and closing rotational movements.

CRANIOMANDIBULAR ARTICULATION

The methods of examining jaw movements and occlusion vary; however, there are basic anatomic and physiologic principles that must be known in order to carry out these diagnostic procedures. The anatomy of the craniomandibular articulation is important to the dentist and especially to the prosthodontist because of the relationship of the joint motions to the placement or positioning of artificial teeth and the influence these motions have on the allowable occlusal morphology of recusped teeth.

The temporomandibular joint components are the articular fossa, the articular tubercle, the condyle of the mandible, the articular disc, the capsular ligament, the

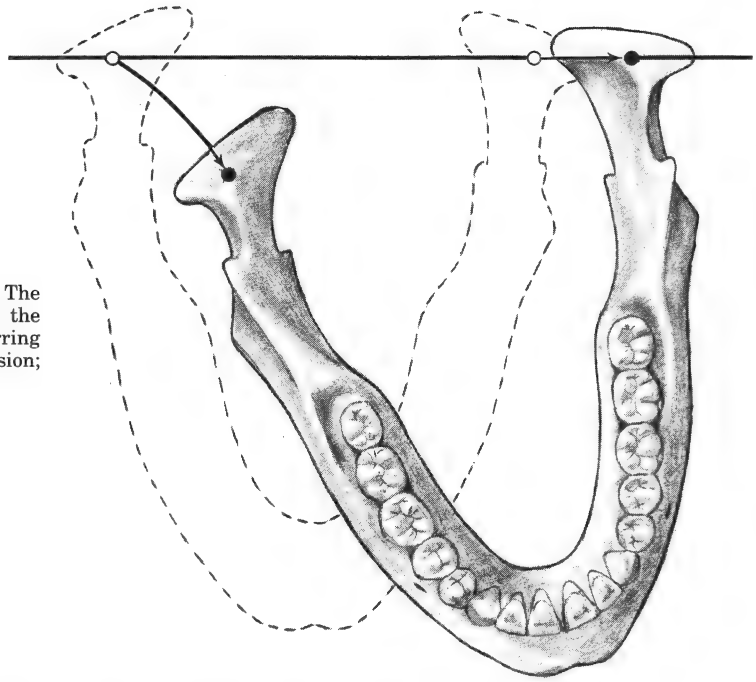


FIGURE 32–1 Lateral movement of the mandible. The right condyle is the orbiting condyle; the left is the rotating condyle. Transtrusion (side shift) is occurring toward the left. The left condyle exhibits laterotrusion; the right exhibits mediotrusion.

synovial sacs (Fig. 32–2), and the temporomandibular ligament (Fig. 32–3A).

The *articular fossa* (glenoid fossa) and the *articular tubercle* (articular eminence) form the concavoconvex contour of the articular surface of the temporal bone. The articular surface of the fossa and tubercle is covered with a layer of dense fibrous connective tissue. This covering varies in thickness, with the deepest portion covering the posterior slope of the articular tubercle.

The *condyle* of the mandible is an ellipsoid bar of bone that serves as the articulating surface of the mandible. Its articular surface is also covered with a thin layer of fibrous connective tissue.

The *articular disc* is a relatively thin plate of dense

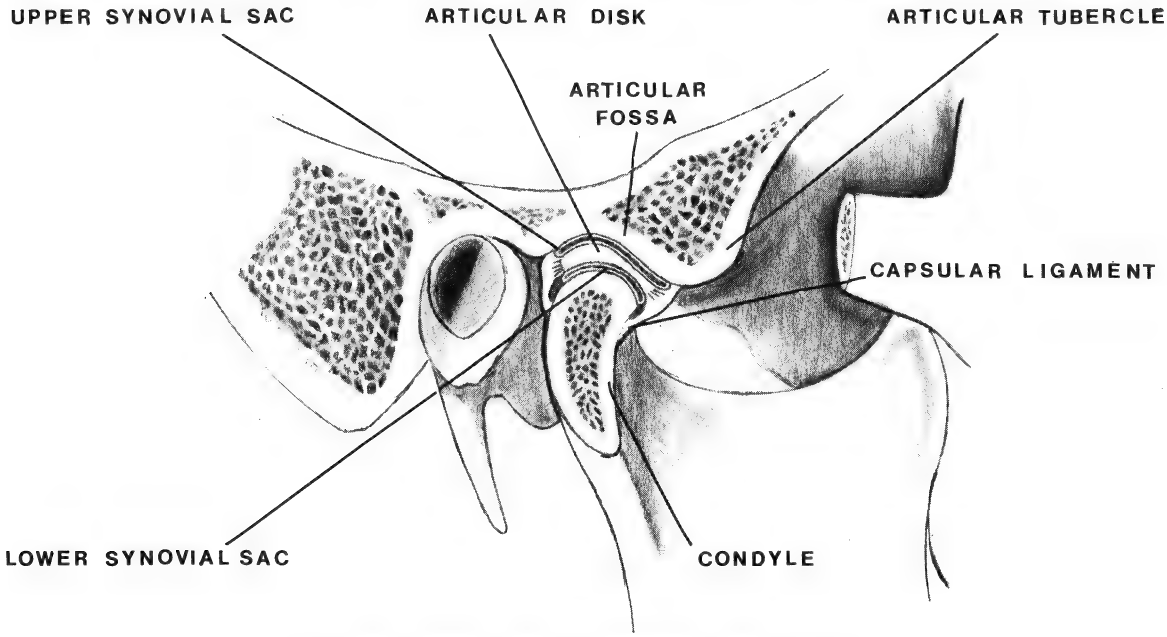


FIGURE 32–2 Sagittal section of temporomandibular joint.

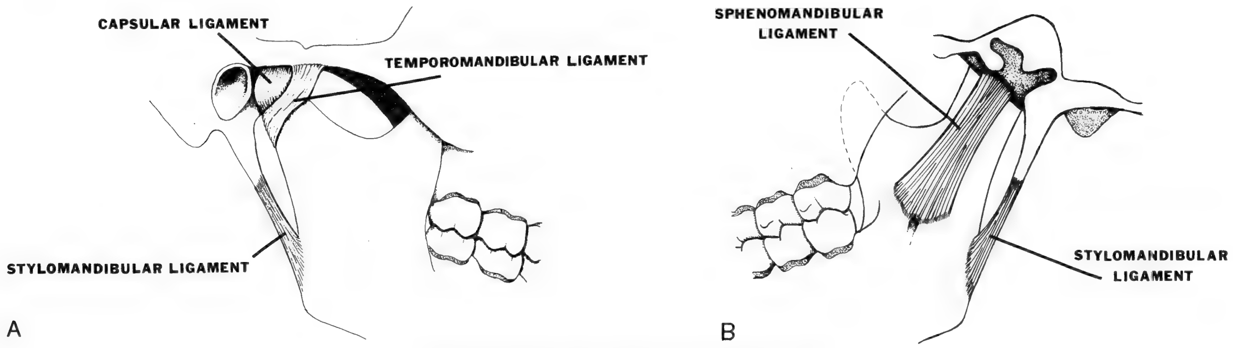


FIGURE 32–3 Craniomandibular Ligaments

A, Lateral view.
B, Medial view.

fibrous connective tissue that separates the articular fossa and the mandibular condyle to create a compound joint. It is oval in shape, and its mediolateral measurement is greater than its anteroposterior dimension. Its edges are attached to the inner walls of the surrounding articular capsule and to the tendon of the lateral pterygoid muscle, which penetrates the enclosing capsule of the joint. The concavoconvex superior surface and the concave inferior surface serve as articulatory surfaces, and in healthy jaws the disc moves with the condyle. It has been suggested that the attachment of the lateral pterygoid muscle enables the disc to be moved independently of the condyle. Articular discs vary in shape, size, and thickness, not only for different individuals but in the same individual on either side of the jaw. The retrodiscal tissue is heavily vascular; however, the articulating surfaces have no blood supply.

The *capsular ligament* is a thin loose fibrous sac that encloses the joint cavities. The origin of this joint capsule is at the periphery of the articular fossa of the temporal bone, and it inserts posteriorly at various levels into the neck of the condyle. Within the joint space, fibers from this capsule attach to the edge of the articular disc around its entire circumference.

The attachment of the capsular ligament to the disc separates the joint into two separate cavities known as *synovial sacs*, which are filled with *synovial fluid*. This fluid is secreted by specialized *synovial membrane cells* and supplies lubrication and nourishment to the articulating parts.

The *temporomandibular ligament* consists of two separate layers that form a wide superficial band of fibers originating from the lateral aspects of the zygomatic process and articular tubercle. Extending inferiorly and posteriorly on the surface of the capsular ligament, the outer band inserts on the lateral and posterior margins of the neck of the condyle, thus strengthening the capsular ligament laterally. This portion of the ligament limits the movement of the condyle as it rotates and translates. The inner narrow band of fibers originates on the crest of the articular tubercle and passes back horizontally and attaches to the lateral aspect of the mandibular condyle and to the back of the disc. This horizontal band limits the backward movement. Sicher* states that this inner band prevents posterior displacement of the condyle. Aarstad* found, by dissection of the temporomandibular joint, that the terminal hinge action of the mandible could be displaced posteriorly only after detachment of the temporomandibular ligament.

*Du Brul, E: Sicher's oral anatomy, 7th ed. St. Louis, MO., C. V. Mosby Company, 1980, p. 174.

ACCESSORY LIGAMENTS

The *sphenomandibular ligament* is a thin broad band of fibers that extends downward from the angular spine of the sphenoid bone to the lingula, the small tongue-shaped extension of bone on the medial aspect of the mandibular ramus (Fig. 32–3B). The lateral surface of the ligament is adjacent to the lateral pterygoid muscle, with the medial surface in neighborly contact with the outermost fibers of the medial pterygoid muscle.

The *stylomandibular ligament* consists of a bandlike extension of cervical fascia that is derived from a part of the capsule of the parotid gland (Fig. 32–3B). It is attached above to the tip of the styloid process of the temporal bone, from which it extends downward and forward to the posterior border of the ramus of the mandible. Neither the sphenomandibular ligament nor the stylomandibular ligament has a direct anatomic connection with the temporomandibular joint; hence, they are known as *accessory ligaments*.

It is the responsibility of these ligaments to *limit* the movement of the mandible.

MUSCULATURE OF MANDIBULAR MOVEMENT

The rotary and translatory movements of the mandible are produced by the action of the related muscles.

All muscles attached to the mandible, and some that have no direct attachment, are capable of participating in mandibular movement. The actions of the four pairs of muscles described here are the major sources of energy for mandibular movement. Therefore these muscles have been classified as the muscles of mastication.

*Aarstad, T: The capsular ligaments of the temporomandibular joint and retrusion facets of the dentition in relationship to mandibular movements. Oslo, Norway, Akademisk Forlag, 1954.

Masseter Muscle. The masseter, a strong thick muscle, is one of the most powerful closing muscles of the jaw. When the jaws are clenched, the bulging of its contracted fibers can be seen easily in many individuals. The masseter consists of two sets of fibers, superficial and deep (Fig. 32–4). The outer, or superficial, portion of the muscle is the larger of the two. It has its origin in a strong tendinous aponeurosis on the zygomatic process of the maxillary bone and along the anterior two-thirds of the zygomatic arch. From these areas of attachment, the superficial fibers extend downward and backward and insert into the lateral surface of the ramus and the angle of the mandible. Deep to these fibers, the remaining small portion of the muscle arises from the inferior surface of the zygomatic arch. Its fibers extend downward but, unlike the superficial fibers, take a forward direction and insert into the lateral surface of the ramus and the base of the coronoid process of the mandible. The principal function of the masseter muscles is to elevate the jaw; however, they may also assist in protrusion and retrusion.

Temporalis Muscle. The origin of this muscle is from the entire extent of the temporal fossa. It inserts into the apex and lateral surface of the coronoid process and the mandibular notch. The principal function of the temporalis muscles is to elevate the jaw; however, they may assist in protrusion and retrusion (Fig. 32–5).

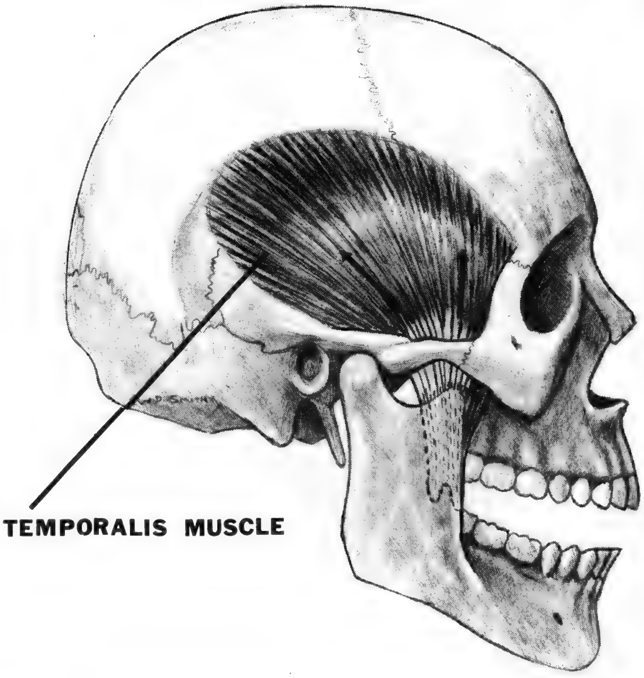


FIGURE 32–5 Temporalis muscle, lateral view.

Medial Pterygoid Muscle. The medial pterygoid muscle has a strong tendinous origin in the pterygoid fossa, with some of its fibers originating on the tuberosity of the maxilla and the adjacent pyramidal portion of the palatine bone. The fibers of this muscle pass downward and backward and insert on the medial aspect of the angle of the mandible (Fig. 32–6A). When the right and left medial pterygoids contract together, the jaw is raised. When the muscle of one side acts alone, the jaw is pulled toward the opposite side. The action of the muscle assists in the forward motion of the jaw and also in its lateral movements. The masseter, together with the medial pterygoid muscle, straps the ramus of the mandible. This strapping or splinting of the jaw by these two muscles is so effective that fractures across the ramus of the mandible usually result in little or no displacement of the parts.

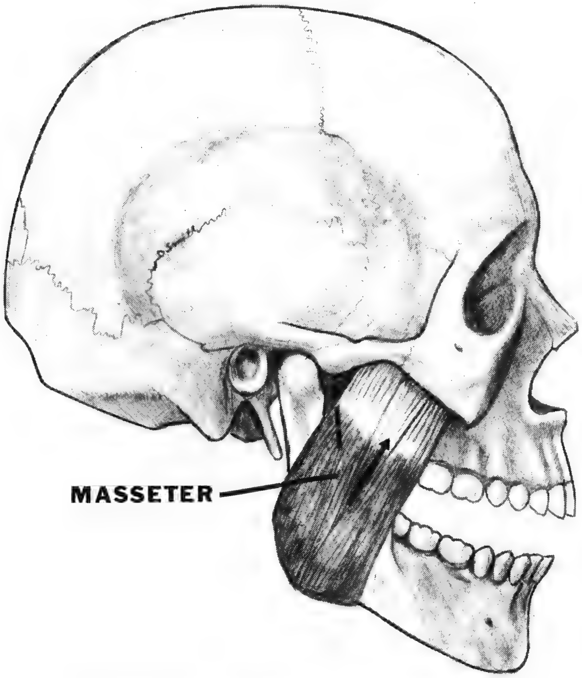


FIGURE 32–4 Masseter muscle, lateral view.

Lateral Pterygoid Muscle. This muscle consists of a superior and inferior head (Fig. 32–6B). The fibers of the superior head, which is the smaller, pass outward from under the great wing of the sphenoid bone and the superior surface of the lateral pterygoid plate. The fibers of the inferior head, which are stronger and thicker than those of the superior head, pass from the outer surface of the lateral pterygoid plate to fuse with the superior portion of the muscle near the neck of the mandibular condyle. The fibers insert into the fibrous capsule that surrounds the temporomandibular joint, into the articular disc, and into the neck of the condyle. Contraction of the inferior head results in a forward movement of the mandible. The superior head is inactive during opening (Fig. 32–7A) and functions only during closing to stabilize the condyle and disc against the articular tubercle (Fig. 32–7B).

The coordinated alternate action of the right lateral pterygoid muscle with the elevators of the left side and of the left lateral pterygoid with the elevators of the right side produces the cyclic movements of chewing.

The temporalis, the masseter, and the medial pterygoid muscles elevate the jaw and have great power in keeping the teeth clenched. The mouth opens by the relaxation of these muscles and by the influence of the weight of the mandible coordinated with the contraction of the suprahyoid and infrahyoid groups of muscles, the platysma, and the lateral pterygoid muscles.

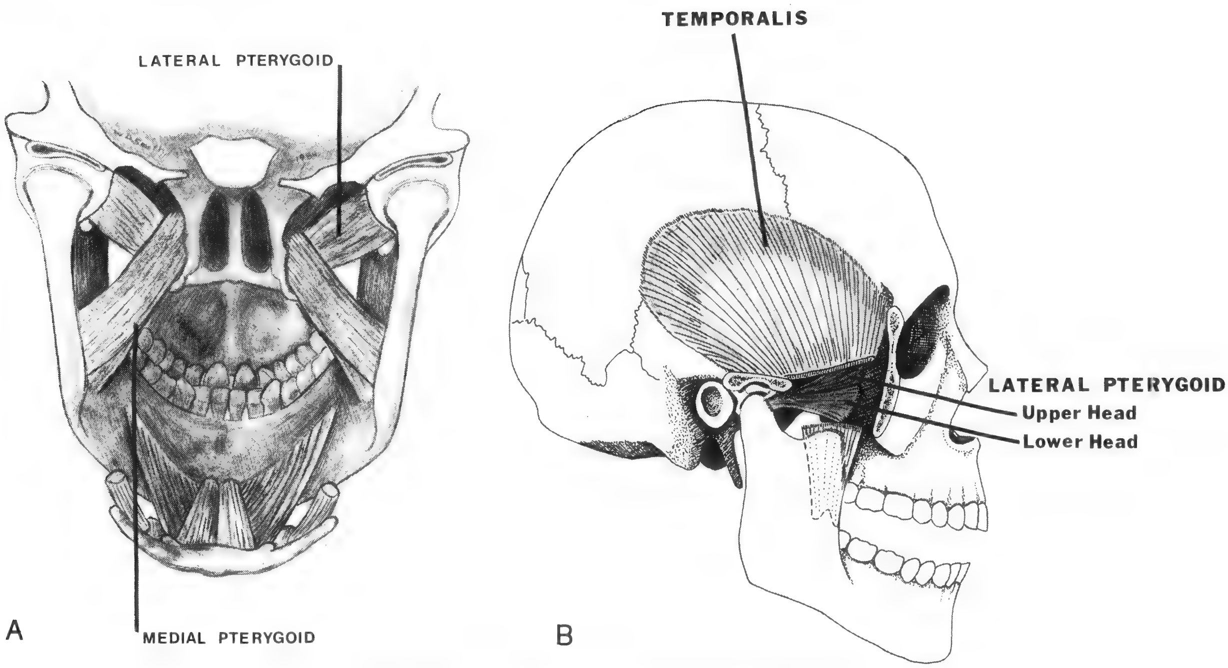


FIGURE 32–6 Medial and Lateral Pterygoid Muscles

A, Posterior view.
B, Lateral view.

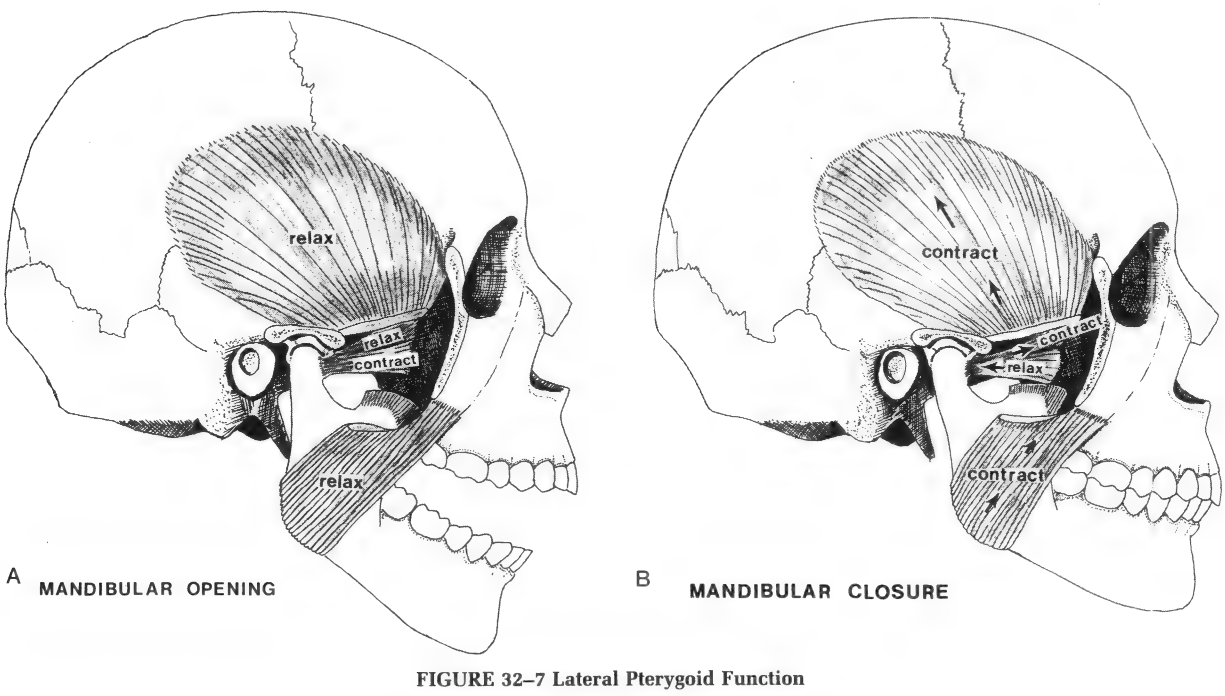


FIGURE 32–7 Lateral Pterygoid Function

A, Opening.
B, Closing.

The hyoid bone, by the action of its associated muscle groups, provides a fulcrum for the action of the tongue and with the action of the suprahyoid and infrahyoid muscle groups, contributes to the functions of phonation, deglutition and mastication.

NEUROMUSCULAR CONTROL OF MANDIBULAR MOVEMENT

A consideration of muscle action should include an awareness of the extent of mandibular motion. The muscles usually referred to as participants in movements of the jaw do not function equally at all times. The degree of movement attained is governed by the amount of energy employed; therefore, muscle action may produce changes in the magnitude but not in the character of jaw movement, since this is determined largely by the morphology of the temporomandibular joint.

Muscles are capable of contracting isotonically or isometrically. *Isotonic muscular contraction* takes place in the absence of significant resistance with shortening of muscle fibers and without great increase in muscle tone. The associated skeletal parts are moved by this type of contraction.

Isometric muscular contraction takes place against resistance without significant shortening of muscle fibers and with marked increase in muscle tone. The associated skeletal parts resist movement by this type of contraction.

Sicher* describes three distinct roles that a muscle can play in providing the power to move associated skeletal parts. First, a muscle can contract isotonically and shorten, resulting in movement; second, it can contract isotonically and then lengthen and remain tense to act as a balancer for the antagonist muscles; third, a muscle can contract isometrically, without changing length, and act as a *stabilizer*. Isometric contraction brought about by the stress of deflective occlusal contacts may produce an interruption in the rearward movement of the mandible that could result in a pseudocentric relation.

*Du Brul, E: Sicher's oral anatomy, 7th ed. St. Louis, MO., C. V. Mosby Company, 1980, p 174.

MANDIBULAR MOVEMENT

The craniomandibular articulation is a *compound diarthrodial* joint. A compound joint is composed of three or more bones, and although the articular disc is not a bone, it functions as a nonossified bone, creating a compound joint. *Diarthrosis* describes a form of articulation that permits considerable change in position of the articulated parts by a simple gliding motion. The temporomandibular joint has a diarthrosis in which the articulating surfaces are capable of gliding on each other with or without axial motion. The joint is also classified as a ginglymoarthrodial articulation. The term *ginglymus* describes a *hinge joint* that admits motion in one plane only.

The mandible is capable of producing ginglymoid action by *rotation* (Fig. 32–8A) around the transverse axis common to the condyles in opening and closing movements. Also, the mandible is capable of diarthrodial action by the *translation* (Fig. 32–8B) of the articular discs and condyles in their relation to the temporal portion of the articular fossa. The mandible, therefore, is capable of moving by rotation and by translation, either singly or in combination, and these movements may be identified with reference to the three cranial planes (Fig. 32–9).

Centric relation, or the physiologic centering of the condyle in relation to the cranium, has been defined by some authorities as the rearmost, uppermost, midmost position of the condyle in the articular (glenoid) fossa. Recently, many authorities have eliminated "rearmost" from this definition. In any case, there is an absence of translation of the mandible at this centric position. Centric relation can be maintained during an opening

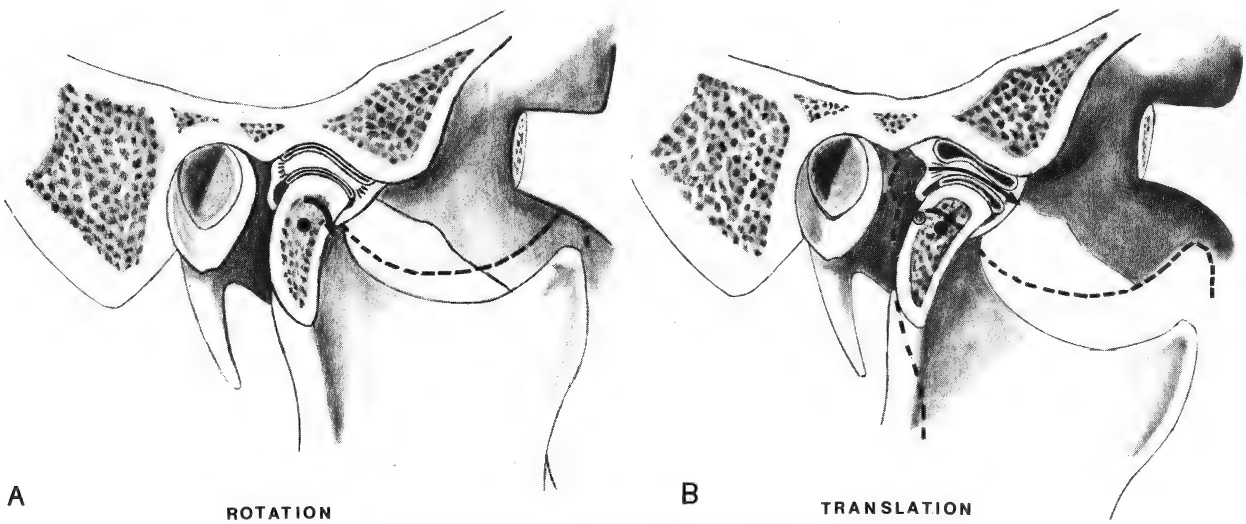


FIGURE 32–8 Temporomandibular Joint Movements

A, Rotation around the transverse axis.
B, Translation and forward movement of disc and condyle.

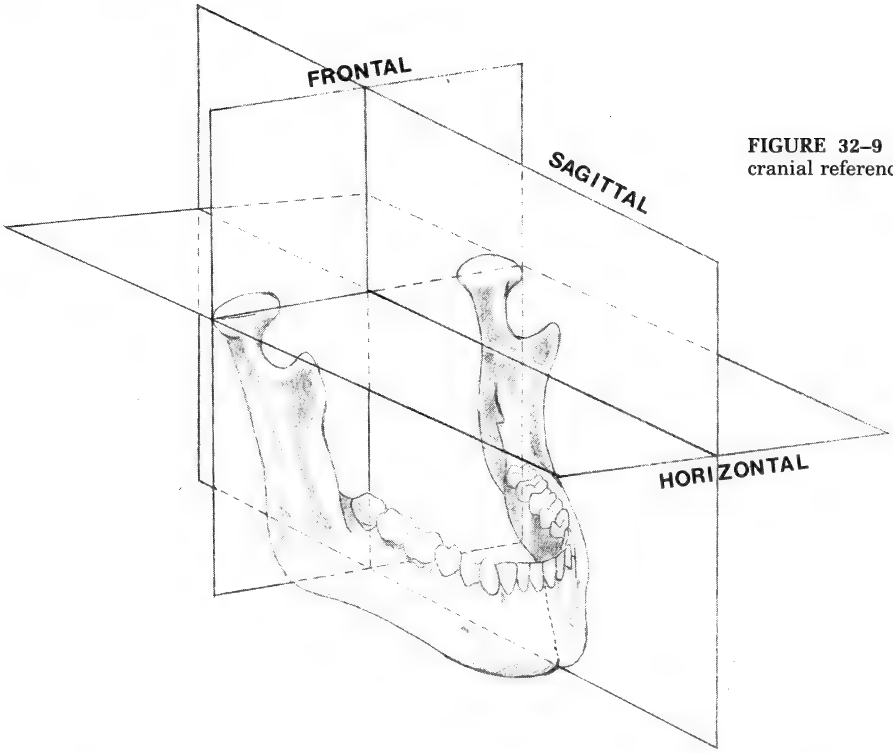


FIGURE 32–9 Relationship of mandible to cranial reference planes.

rotational movement; therefore, centric relation is the untranslated hinge position of the mandible in its relation to the cranium.

Rotation

Mandibular rotation occurs around the rotational centers within the condyles and takes place in the lower chamber of the temporomandibular joint. These rotational centers are produced by the intersection of three axes of rotation (Fig. 32–10).

Horizontal Axis

The mandible is capable of rotating around this horizontal, or hinge, axis to produce opening and closing movements. This rotation can occur in any degree of protrusion as well as in centric relation.

Vertical Axis

Movement around the vertical axis of one condyle produces rotation of the mandible in the horizontal plane, which results in a lateral excursion toward the side of the rotating condyle. The condyle around which the rotation occurs is described as the rotating, or working, condyle, and the opposite condyle is the orbiting, or nonworking, condyle.

Sagittal Axis

As lateral excursions of the mandible are made, the orbiting condyle travels downward as well as forward, producing a rotation around a second horizontal axis that is called the sagittal axis. This axis intersects the rotating condyle.

Translation

Translation of the mandible occurs as muscular contraction produces a change in the relationship of the

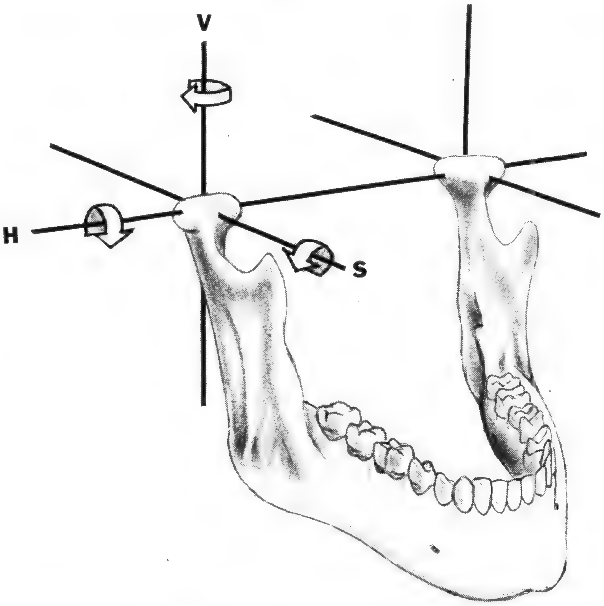


FIGURE 32–10 Mandibular rotational axes. V, vertical axis; H, horizontal axis; S, sagittal axis.

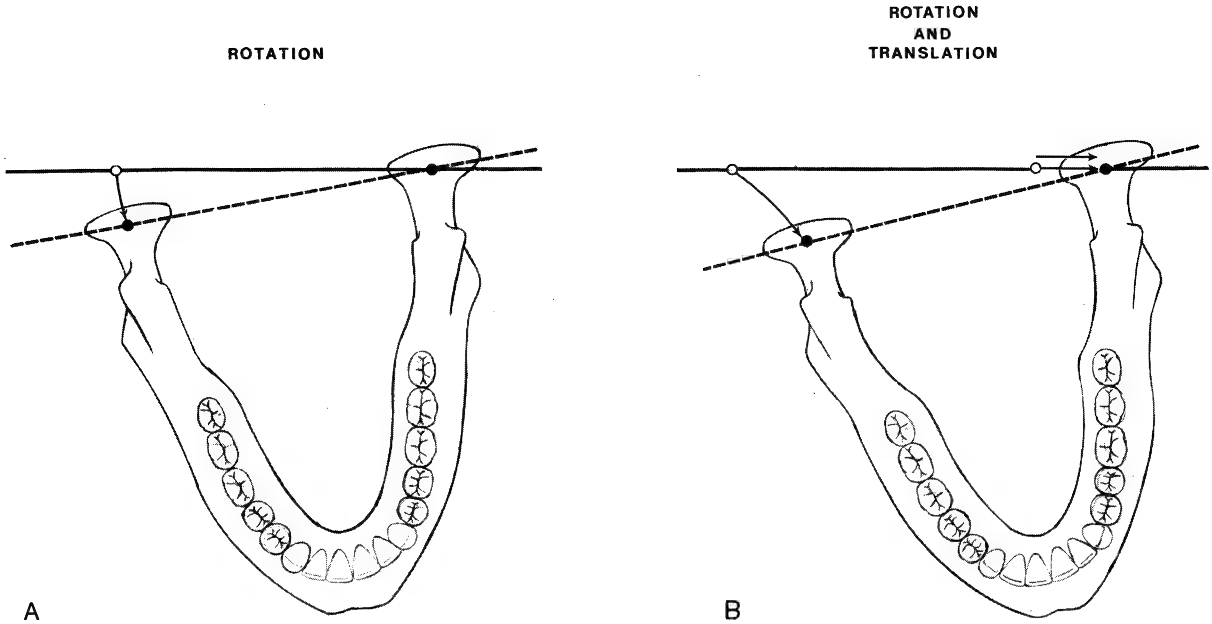


FIGURE 32–11 Left Lateral Mandibular Movement
A, Rotation only.
B, Rotation and translation combined.

condyle and its articular disc with the articular fossa. This action takes place in the upper compartment of the temporomandibular joint and may occur simultaneously in all three cranial planes.

Figure 32–11 illustrates the combined effect of rotation and translation during a left lateral movement of the mandible as it occurs in the horizontal plane.

EFFECT OF CRANIOMANDIBULAR JOINT ANATOMY ON MANDIBULAR MOVEMENT

The mandible is moved by the energy that is transmitted through the associated muscles. The ligaments of the temporomandibular joint, along with the accessory ligaments attached to the mandible, provide limits to these movements. The character of these movements is determined by the morphology of each joint. These movements not only vary from one individual to another but also may vary between the right and left temporomandibular joints of the same individual.

The paths of these condylar movements and the location of the rotational centers can be measured and transferred from the patient to a fully adjustable articulator. After adjustment, the articulator becomes a valuable guide in diagnosing occlusal relations and fabricating restorations. Stuart* described these condylar factors as determinants of occlusal morphology. Because of their effect on acceptable cusp height and fossa depth and the allowable ridge and groove directions of the teeth, they have come to be known as the *posterior determinants* of occlusion.

These condylar controls and their effects on tooth morphology are described here:

Path of the Orbiting Condyle. This is the descent or detrusion of the orbiting condyle in relation to a horizontal cranial reference plane. The greater the angle of this path, the greater is the allowable cusp height and the deeper the fossae may be. With a lesser angle, the cusps must be shorter and the fossae must be shallower (Fig. 32–12).

Side Shift. This is a transtrusion or lateral bodily shifting of the mandible as a lateral movement is made. This movement is produced by a combination of rotation and translation in both the horizontal and frontal planes. If translation occurs at a greater rate nearer centric relation, an immediate lateral shifting of the mandible is produced. The greater the immediate side shift, the shorter is the allowable cusp height. The presence of immediate side shift also requires a more mesial positioning of the oblique grooves and ridges on the mandibular teeth and a more distal positioning of the oblique grooves on the maxillary teeth than would be needed if no immediate side shift occurred (Fig. 32–13A).

During a right working movement, the greater the mediotrusion of the left condyle (the orbiting condyle) that is produced by side shift, the greater must be the lingual concavity of the maxillary right canine in order to allow a smooth cyclic chewing movement without conflict (Fig. 32–13B).

Intercondylar Distance. The distance existing between the rotational center of one condyle and the

*Stuart, C and Stallard, H: Oral rehabilitation and occlusion, vol I and II, San Francisco, CA, University of California Press, 1972, pp 43–53.

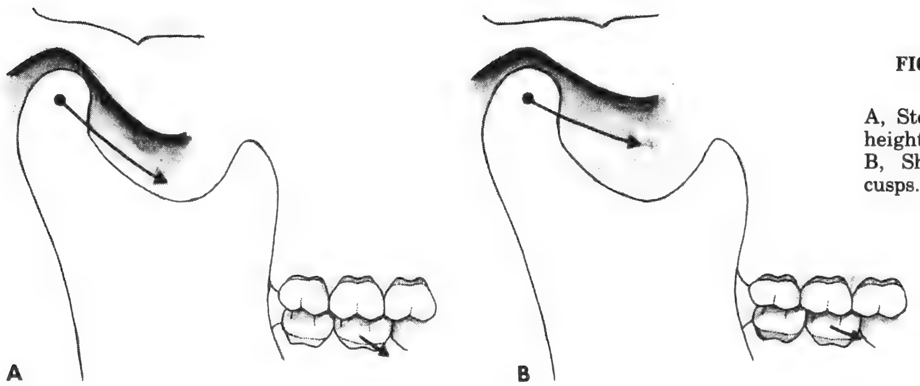
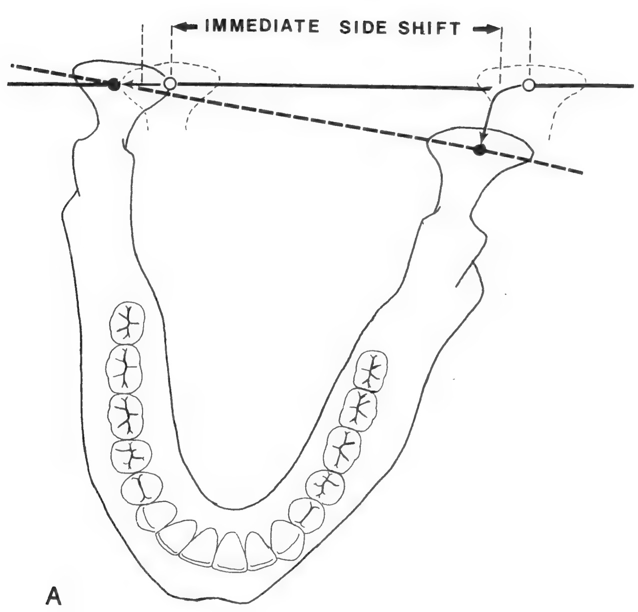
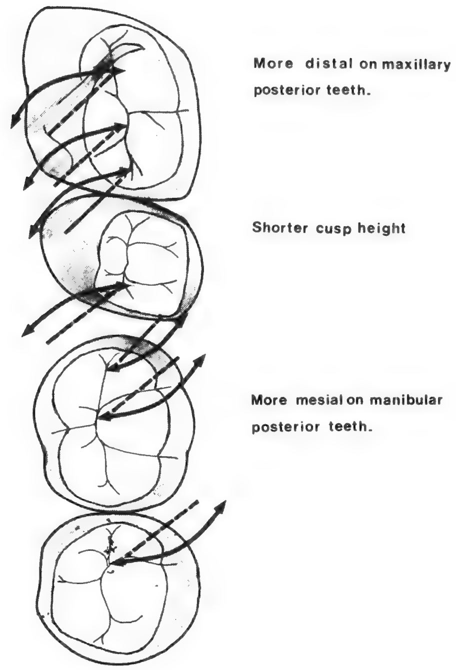


FIGURE 32–12 Path of Orbiting Condyle.

A, Steep path allowing greater cusp height.
B, Shallow path requiring shorter cusps.





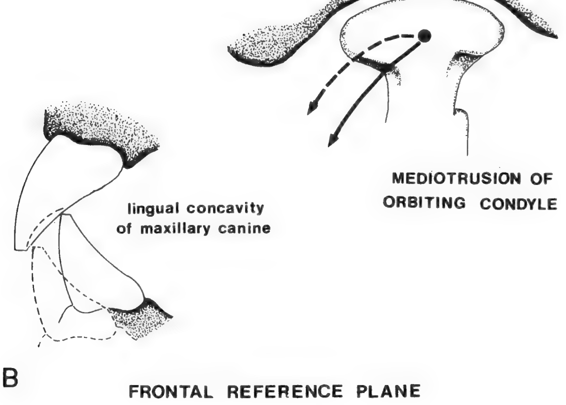


FIGURE 32–13 Side Shift

A, Effect on posterior groove form and cusp height.
B, Effect on lingual contours of maxillary canine.

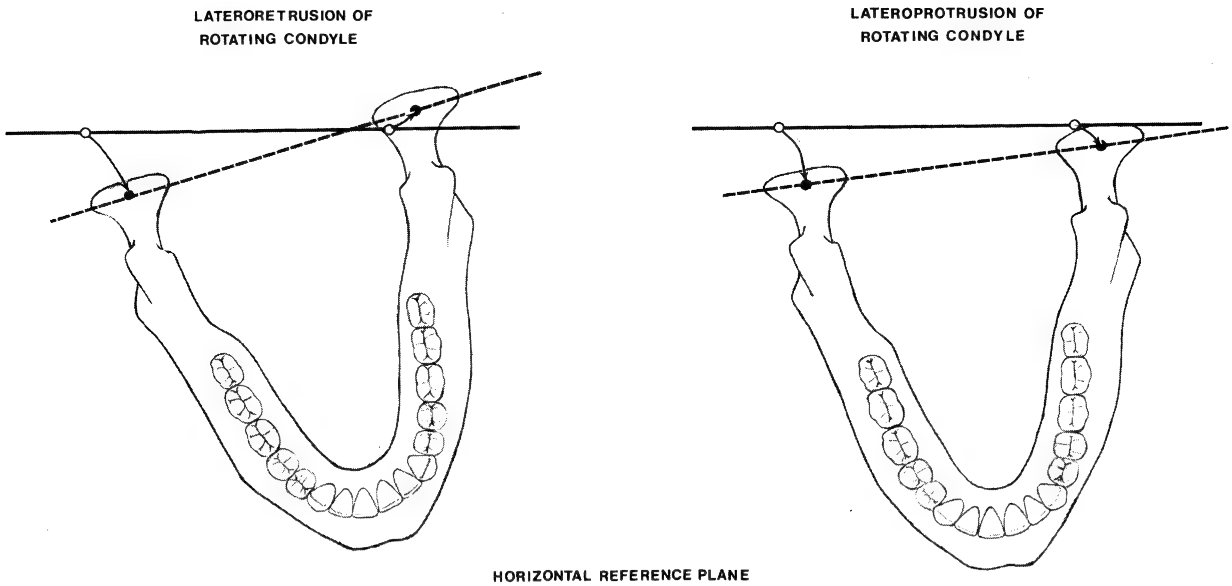


FIGURE 32–14

rotational center of the opposite condyle is the effective *intercondylar distance*. A larger than average intercondylar distance requires more distal positioning of the oblique grooves and ridges on the mandibular teeth and more mesial positioning of these grooves and ridges on the maxillary teeth. Conversely, a smaller intercondylar distance requires a more mesial positioning of the oblique grooves and ridges on the mandibular teeth and a more distal positioning of these grooves and ridges on the maxillary teeth.

Path of the Rotating Condyle. As already stated, the term *laterotrusion* describes any lateral movement of the rotating condyle. In the horizontal plane, *lateroprotrusion* is an outward and forward movement, and *lateroretrusion* is an outward and backward movement of the rotating condyle (Fig. 32–14). These horizontal movements, because of their anteroposterior component, affect the allowable ridge and groove directions of the occlusal surfaces of the teeth. For the mandibular teeth, lateroprotrusion requires a more distal positioning and lateroretrusion a more mesial positioning of the grooves and ridges. In the maxillary arch, the opposite is true.

As observed in the frontal plane, *laterosurtrusion* is an outward and upward movement of the rotating condyle, and *laterodetrusion* is an outward and downward movement (Fig. 32–15). These movements in the frontal plane, because of their vertical components, affect the depth of the grooves, the angle of the ridges, and the height of the cusps (Fig. 32–16). Laterosurtrusion demands shallower grooves and less cusp height. Laterodetrusion allows deeper grooves, steeper ridge angles, and greater cusp height.

The path of the rotating condyle affects the path of the mandibular canine on the working side and influences the amount of allowable lingual contour of the opposing maxillary canine (Fig. 32–17).

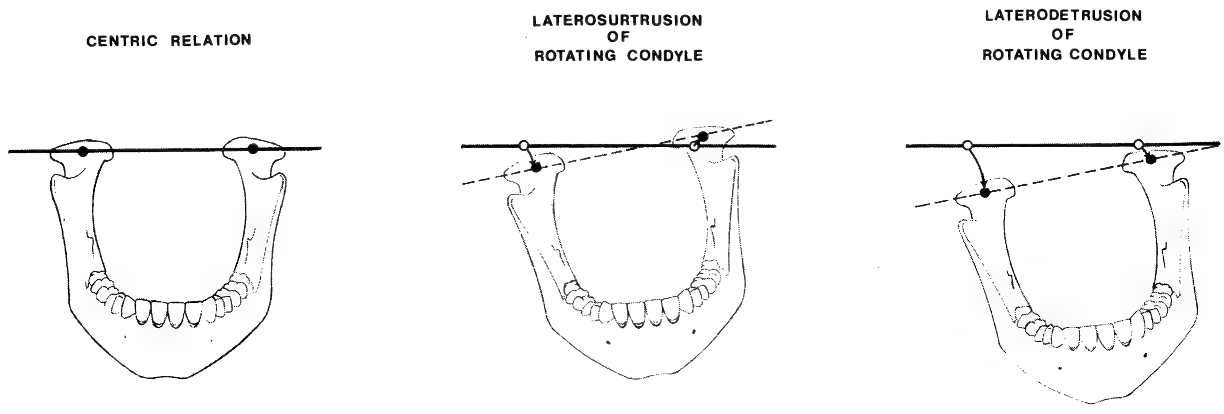


FIGURE 32–15

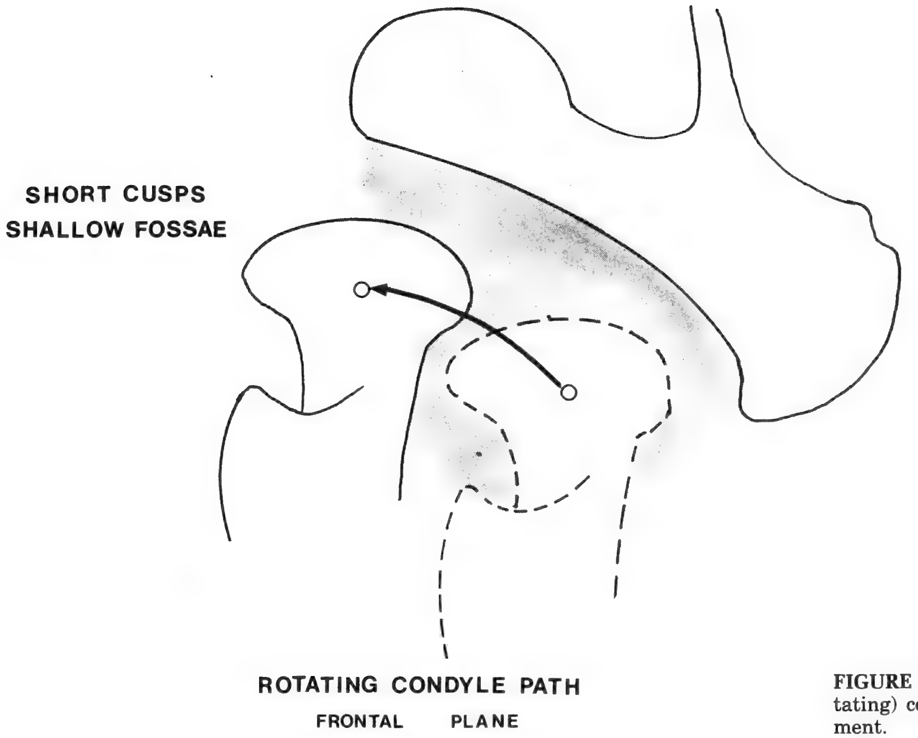
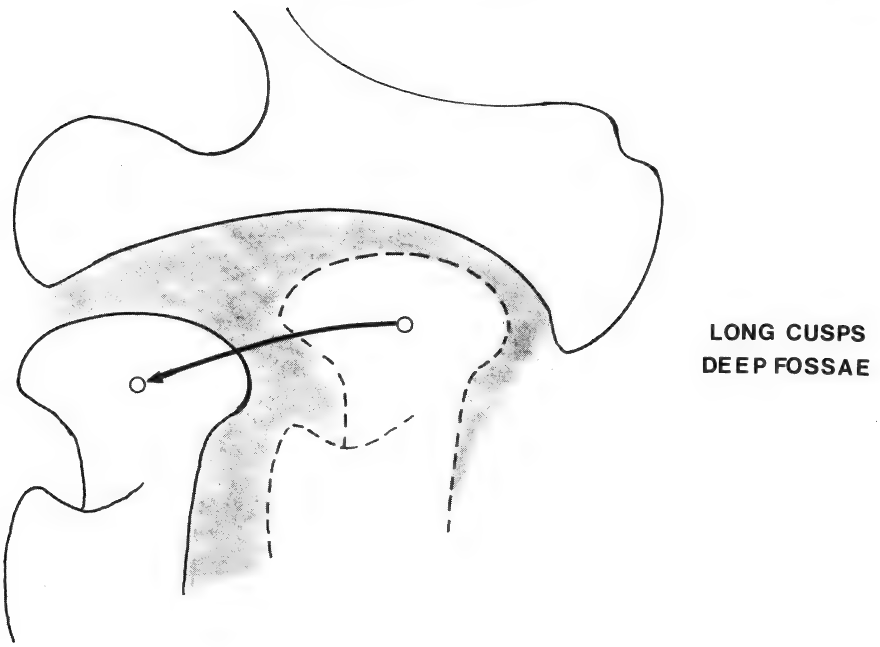


FIGURE 32–16 Frontal view of right (rotating) condyle and right working movement.



THE EFFECT OF OCCLUSION ON MANDIBULAR MOVEMENT

The unique design of the articulation of the mandible to the cranium provides bilateral roving fulcrums capable of allowing complex jaw movement. In addition to its complex jointing to the cranium, the mandible carries one-half of the teeth whose positions and contours, together with the manner in which they meet the opposing maxillary teeth, can influence the movement within the joint and determine the positions of the condyles and discs at maximal intercusping of the teeth.

The factors found within the dentition that are capable of influencing mandibular movement are called the

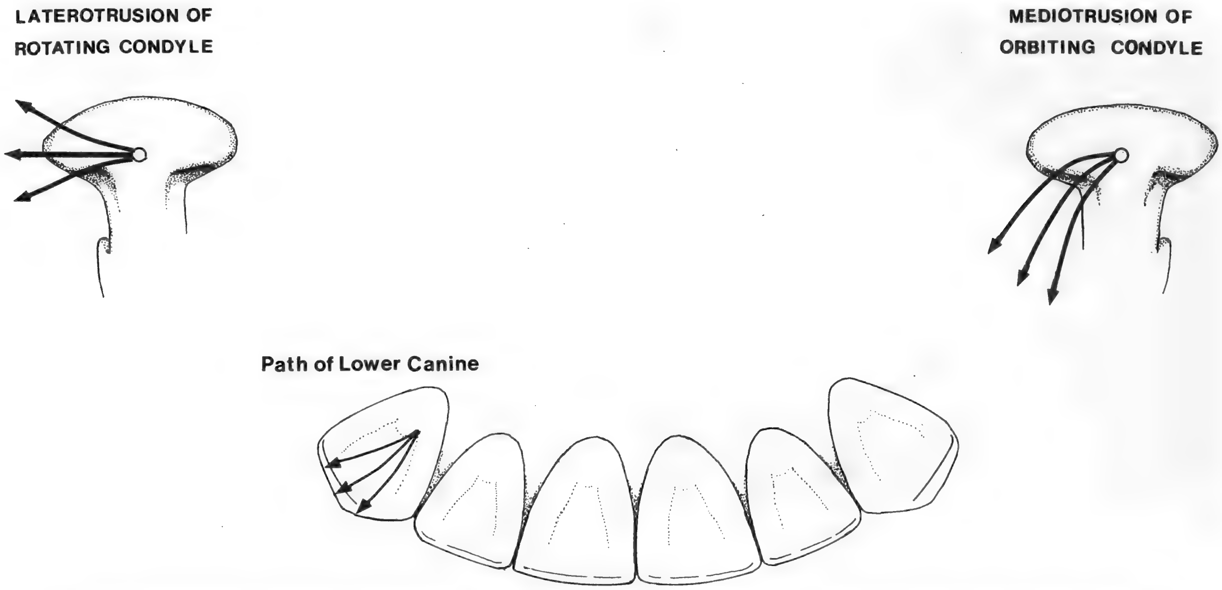


FIGURE 32–17 Right working movement. Effect of direction of laterotrusion on mandibular right canine pathway.

anterior determinants of occlusion. These determinants and their effects on workable tooth morphology are the occlusal plane, the curve of Spee, the facial position of the teeth, and the vertical and horizontal overlap of the anterior teeth.

Occlusal Plane. The more the plane of occlusion diverges from the path of the nonworking condyle, the greater is the allowable cusp height. The more nearly parallel the occlusal plane is to the path of the nonworking condyle, the shorter is the allowable cusp height (Fig. 32–18).

Curve of Spee. The effect of the curve of Spee is determined by comparing the plane of each tooth in the curve with the path of the orbiting condyle and applying the same rule as was used for the occlusal plane (Fig. 32–19). The more the plane of each tooth diverges from the direction of the path of the orbiting condyle, the greater is the allowable cusp height. The more nearly the plane of each tooth parallels the path of the orbiting condyle, the shorter is the allowable cusp height.

Facial Position of the Teeth. The position of the teeth in relation to the rotational centers of the condyles and to a horizontal cranial reference plane is transferred to an articulator by means of a facebow, which places the maxillary cast in the proper relationship to the axes of the instrument (Fig. 32–20). Interocclusal records made in centric relation are then used to place the mandibular cast in proper relation to the rotational centers and cranial reference planes. The teeth on the cast then have the same spatial relationship in front of and below the transverse axis of the instrument as the patient's teeth have to the hinge axis of the mandible.

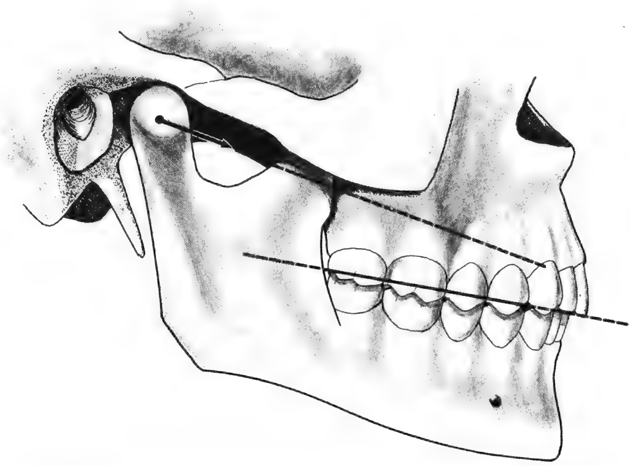


FIGURE 32–18 Left working movement. Occlusal plane divergence from condylar path allowing greater cusp height.

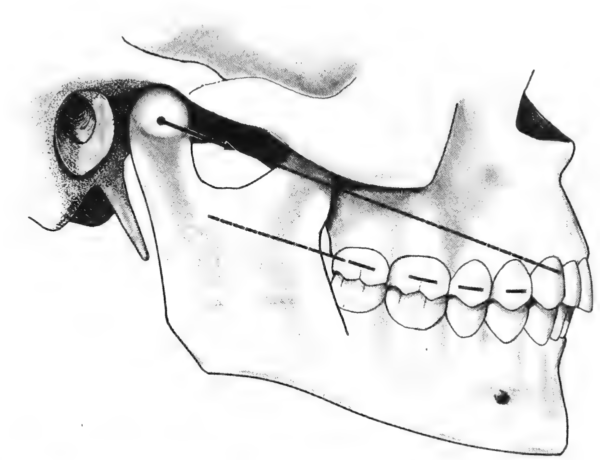


FIGURE 32–19 Left working movement. Variation between curve of Spee and path of orbiting condyle.

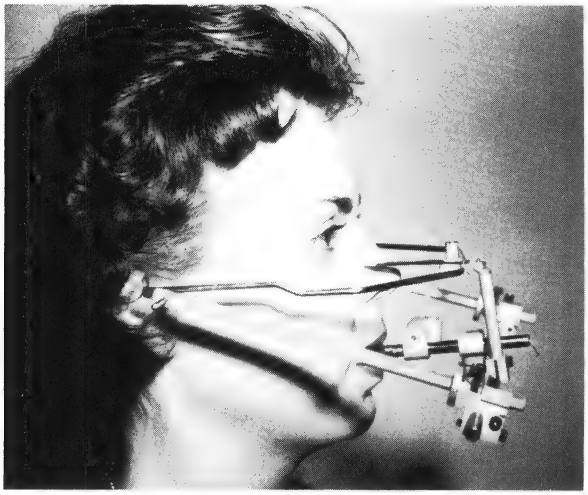


FIGURE 32–20 Facebow used to record relationship of maxillary teeth to hinge axis.

This orientation of the teeth to the transverse axis in all three planes is important because of the effect of tooth position on the acceptable ridge and groove directions of the occlusal surfaces. The more laterally the teeth are positioned relative to the midline, the more mesially the ridges and grooves must be located in the mandibular teeth and the more distally in the maxillary teeth. The more anteriorly the teeth are positioned relative to the rotational centers, the more mesially the ridges and grooves must be located in the mandibular teeth, and the more distally they must be positioned in the maxillary teeth.

The mounting of casts on articulators without the use of a facebow to properly orient the casts to the axes of the instrument may lead to error in developing ridge and groove direction on the occlusal surfaces of restored teeth.

Vertical and Horizontal Overlap of the Anterior Teeth. The greater the vertical overlap of the anterior teeth, the greater is the allowable cusp height (Fig. 32–21). The greater the horizontal overlap of the anterior teeth, the shorter is the allowable cusp height (Fig. 32–22).

TOOTH GUIDANCE DURING MANDIBULAR CLOSURE

The influence of tooth contacts on mandibular movement was described by Posselt* when he identified an envelope of mandibular motion by tracing a point on the incisal edge of a mandibular central incisor (Fig. 32–23). The upper extent of *Posselt's envelope* of motion is a product of tooth contact. The movements of the mandible along all other borders of the envelope and movements within the envelope are without tooth contact and are controlled by the craniomandibular articulation and the quantity of muscular activity. Occlusal contacts, if they are not properly created by natural growth and development, may interfere with these condylar controls so that condylar centricity is lost (Fig. 32–24). Faulty occlusal contours of dental restorations may also produce deflective occlusal contacts, causing the mandible to move away from centric relation closure

*Posselt, U: Physiology of occlusion and rehabilitation, 2nd ed. Oxford, England, Edinburgh, Blackwell Scientific, 1968, p. 44.

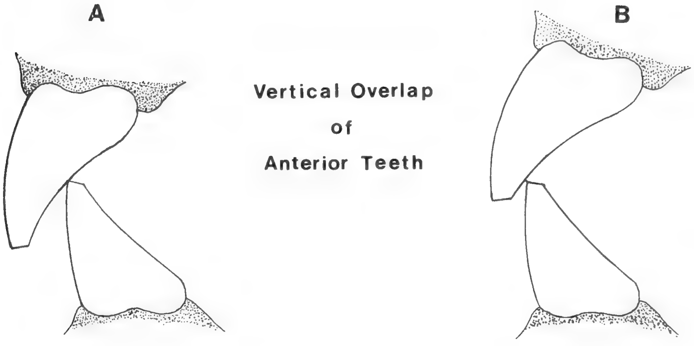


FIGURE 32–21 The greater vertical overlap seen in A produces more separation of the posterior teeth in eccentric movements than would occur in B. The greater the separation the greater is the allowable cusp height.

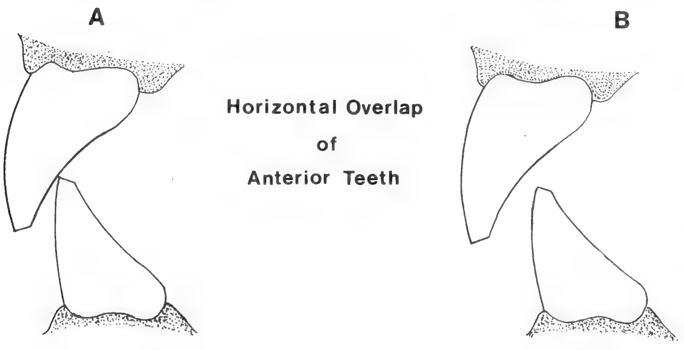


FIGURE 32–22 The greater horizontal overlap seen in B produces less separation of the posterior teeth during eccentric movements than would occur in A. The greater the horizontal overlap the shorter is the allowable cusp height.

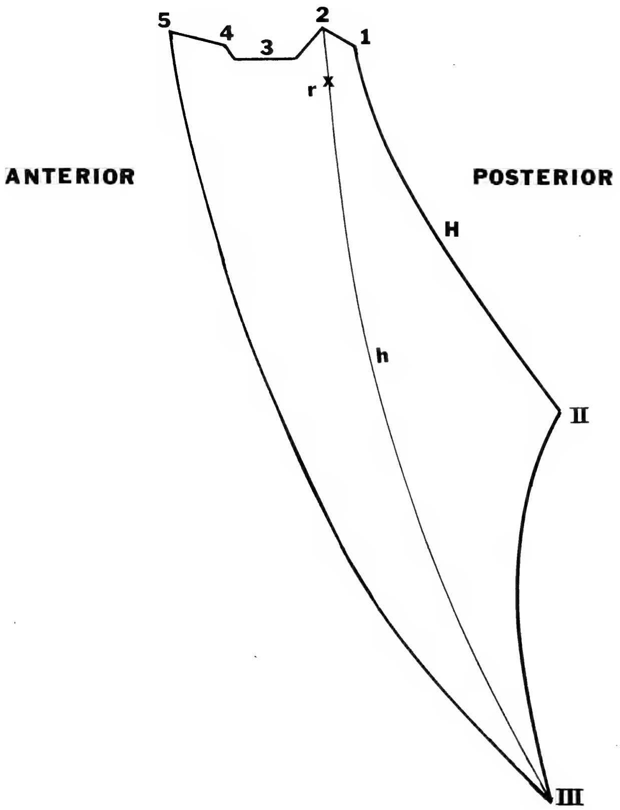


FIGURE 32–23 Left lateral view of Posselt's envelope of mandibular motion. H, the terminal hinge movement; 1, the retruded occlusal contact position; 2, the maximal intercuspal position; 3, the edge-to-edge contact relationship of the anterior teeth; 4, anterior movement to a reversed overlap relationship of the anterior teeth; 5, the maximal protruded contact position; h, the habitual closing movement; r(x), rest position; II, transition from the terminal hinge rotational opening to wider posterior opening as translation combines with rotation; III, the maximal opening.

in order to allow maximal intercuspation of the teeth (Fig. 32–25B). This maximal intercuspal position is an eccentric closure. Premature contacts occurring on the inclines of cusps produce lateral forces on the teeth that create undesirable lateral pressure and tension on the periodontal tissues. While this occlusal force does not cause periodontal disease, it produces increased tooth mobility because of the compensatory widening of the periodontal ligament space.

The craniomandibular articulation allows changes in the relations of its parts in order to accommodate the guiding influence of tooth inclines during the mandible's attempt to reach the position of maximal intercusping. The accommodation produces an *eccentric* maximal intercusping of the teeth. The repeated demands resulting from this intercusping can produce a hypertonicity in the associated muscles beyond their capacity to adapt, and myofacial pain may develop.

Disharmony between condylar centricity and maximal intercusping may also produce excessive wear of the teeth that are responsible for the deflective interferences.

All functions of mandibular movements, such as chewing, speaking, and swallowing, do not require occlusal contacts and more often than not are accomplished without the teeth touching. All functions begin with an opening movement of the jaw. For chewing, a cycle of lateral depressing and elevating movements is generated. This chewing cycle takes place within the envelope of motion and is unique for each individual (Fig. 32–25*A*). Tooth position and tooth morphology may contribute to the development of this cycle; however, extremes in either factor may prevent a smooth cyclic function (Fig. 32–25B). Dental occlusion should be designed so as not to interfere with these muscle-produced and condylar-controlled cyclic actions. This requirement and the purpose of occluding teeth to provide a stable closure of the mandible in centric relation are major considerations in an occlusal scheme that promotes the health of supporting tissues, has a reasonable degree of permanence, and provides efficient comfortable group uses of the teeth (Fig. 32–26).

Posselt's study of mandibular movement revealed that only 10 per cent of the subjects studied demonstrated the occurrence of maximal intercusping while the mandible closed in centric relation. Clinical experience in measuring and evaluating maxillomandibular relations supports this finding, for occlusal interferences on the way to centrically related closure are present in a great percentage of the patients examined. The degree of discrepancy and the consequences of these interferences demonstrate great variety. Some degree of pathologic condition may be found in all of these situations; however, the majority are subclinical and asymptomatic, requiring no change of the occlusion. The protective proprioceptive responses minimize the occurrence of the occlusal conflict of premature contacts by controlling muscle tension and by developing an adaptive arc of closure into the eccentric maximal closing. However, if the damage resulting from these interferences warrants a change, it may be accomplished by one or a combination of the following: (1) occlusal adjustment of the teeth, (2) restoration of form and function by recusping, (3) surgical and/or orthodontic movement of the teeth, and (4) in some situations removal of the teeth that are responsible for the interference.

OCCLUSAL RELATIONSHIPS

The occlusion of the mature healthy mouth with unworn teeth exhibits a loose mortising of the opposing teeth, with the convex surfaces of ridges contacting the convex surfaces of opposing ridges. However, the arrangement of the teeth and the resulting occlusion of the permanent dentition are products of many factors. Hereditary influences, nutrition, metabolic conditions, and environmental factors all help determine the form and position of the teeth.

Two types of cusps are found on the posterior teeth. The lingual cusps of the maxillary teeth and the facial cusps of the mandibular teeth are the *stamp* or *centric holding cusps*. The facial cusps of the maxillary teeth and lingual cusps of the mandibular are the *shearing cusps* (Fig. 32–27). In the occluded relationship, the stamp cusps fit over the central developmental grooves of the opposing tooth and into fossae or embrasures of their opponents. During chewing, the shearing cusps pass in close relation to the opposing stamp cusps as

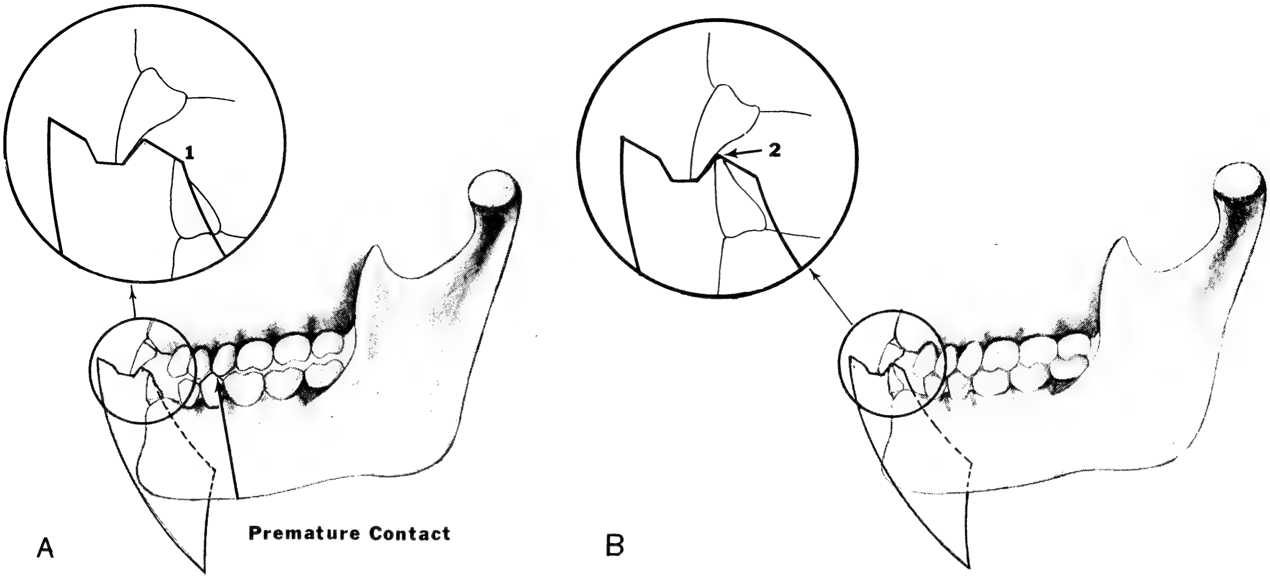


FIGURE 32–24
A, Premature contact between opposing premolars not allowing complete interdigitation of posterior teeth in centric relation (position 1).
B, Maximal interdigitation has been achieved by moving the mandible away from centrically related closure (to position 2).

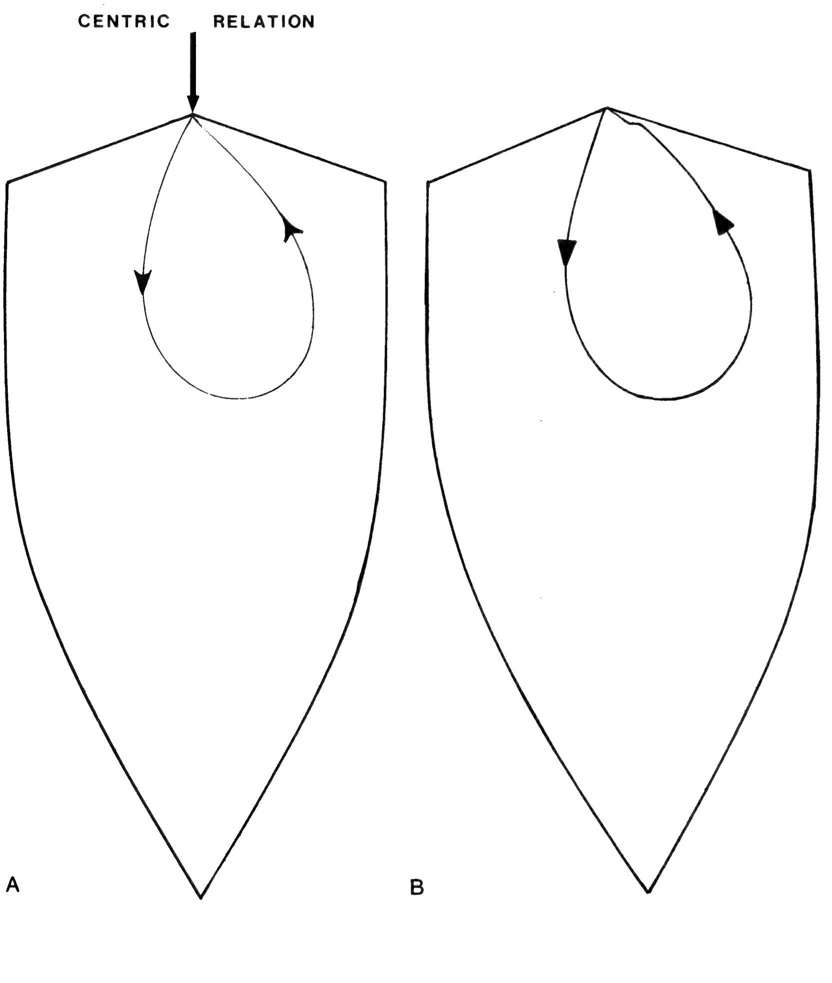


FIGURE 32–25
A, Anterior view of Posselt's envelope of motion including the normal chewing cycle.
B, Premature contact causing abnormal chewing cycle.

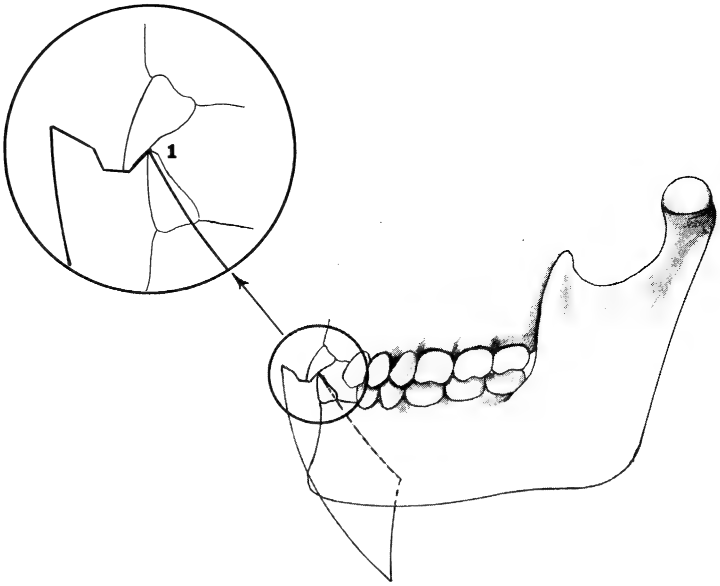


FIGURE 32–26 An occlusal relationship in which the teeth do not interfere with the muscle-produced and condylar-controlled movements, allowing maximal interdigitation of teeth in centric relation. Posselt's envelope therefore would not possess position 2.

occlusion is approached on the working side. Mastication is not a grinding process produced by rubbing together of teeth. Instead, it is accomplished by the action of the ridges of the stamp cusps, which produce multiple incisive actions with the ridges of shearing cusps without tooth contact and by the crushing action of the stamp cusps as they close into opposing fossae. Important to the chewing process is the horizontal overlap of the maxillary teeth, which provides for their grasping and cutting functions in the craniomandibular articulation.

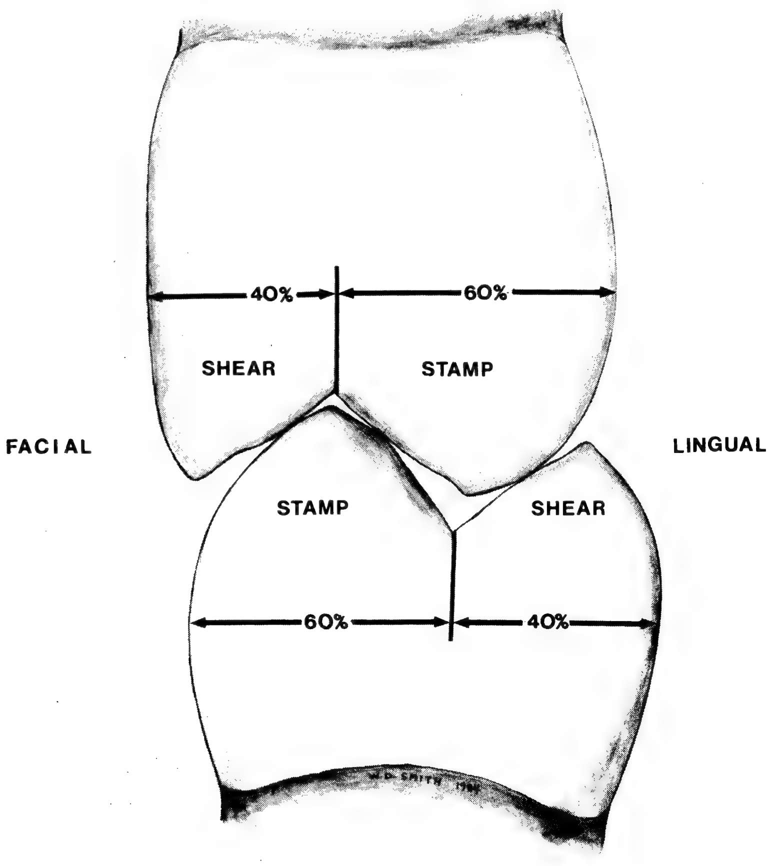


FIGURE 32–27 Diagram of occluding posterior teeth showing stamp and shear cusps. Note that the stamp cusps (those fitting into the central portion of opposing teeth) comprise about 60 per cent of the total faciolingual tooth dimension.

Cusp-Ridge Pattern of Occlusion

The development of the occlusion can result in the fitting of one stamp cusp into a fossa and the fitting of another stamp cusp of the same tooth into the embrasure area of two opposing teeth. This "cusp-ridge" arrangement is a "tooth-to-two-teeth" occlusion or a "cusp-embrasure" occlusal pattern (Fig. 32–28).

Cusp-Fossa Pattern of Occlusion

The development and growth of the masticatory apparatus can also result in most or all of the stamp cusps fitting into fossae. This "cusp-fossa" relation normally produces an interdigitative relation of the cusps and fossae of one tooth with the cusps and fossae of only one opposing tooth (Fig. 32–29). This arrangement may be termed a "tooth-to-one-tooth" occlusion.

Organic Occlusion

Stallard and Stuart* first described a pattern of therapeutic occlusion that featured as its principal unit a stamp cusp fitting into a fossa. The term *organic occlusion* was given to this scheme and is characterized by the following features:

1. The maxillary lingual cusps occlude in the fossae of each mandibular opponent. The mandibular facial cusps occlude in the fossae of each maxillary opponent. The mandibular anterior teeth relate to the lingual surfaces of the maxillary anterior teeth as stamp cusps into fossae.
2. All mandibular teeth occlude simultaneously with the maxillary teeth as the mandible closes in centric relation.
3. In lateral closure, only the canines on the working side occlude. In lateroprotrusive closure, the lateral incisors may share the closure contacts with the canines.
4. In protrusive closure, two or more of the six mandibular anterior teeth occlude with the maxillary incisors.
5. The stamp cusps of the premolar and molar teeth occlude with the opposing fossa with no less than three-point contact in centric relation. No contacts between posterior teeth should occur before centric relation closure is reached from any direction.

OCCLUSAL ADJUSTMENTS

Adjustment of the occlusion by selective grinding and recontouring may be beneficial and necessary in the presence of any of these conditions: evidence of trauma from the occlusion by changes in the periodontium, symptoms of temporomandibular joint dysfunction, habit neuroses (bruxism), excessive tooth mobility, excessive wear of the teeth, and the need for extensive restorative procedures for reasons other than the occlusion.

*Stuart, C and Stallard, H: Oral rehabilitation and occlusion, vol I and II, San Francisco, CA, University of California Press, 1972, pp 110–115.

However, the most common reason for adjusting the occlusion is as a prerestorative treatment. This allows maximal intercusping of the teeth in centric relation and removes premature eccentric contacts that may be responsible for conditioning of the neuromuscular system. The adaptive arc of closure is replaced by the "skeletal" arc of closure, and the patient is permitted to close the jaw in centric relation without deflective occlusal contacts. Under these conditions, temporary restorations or final restorations in opposing quadrants can be made to centric-related closure. There is scant evidence to support the use of occlusal adjustment as a prophylactic measure.

A thorough study of tooth contacts in the mouth and on diagnostic casts mounted on an adjusted articulator should be made to determine whether occlusal refinement can be beneficial. Adjustments should be made on the mounted casts prior to making the changes in the mouth. The diagnostic equilibration provides valuable information by revealing the extent of reduction that is required to establish the desired relations. There are circumstances that present such malalignment of jaws or teeth, or both, that correction is not possible by occlusal adjustment. Alternative treatment plans may be considered before irreversible change has been made in the mouth. A visible record of the areas that are changed can be made by first coloring the occlusal surfaces of the casts with a water-base poster paint. Any surface alteration is evident by the absence of the color (Fig. 32–30). Use of a serial record of all changes in an effort to produce a guide for making the changes in the mouth is of little value.

Occlusal adjustment is accomplished by selective reshaping of the ridges of cusps. Changes are made in the angles of the marginal ridges, cusp height reduction, and reduction of the sulcus by reducing the angles of the triangular and oblique ridges. Care must be exercised not to create flat areas while these reductions are being made. The rounded contours of the cusps and ridges should be maintained, and the finished contours should be polished. The instruments used for these procedures may vary because of the personal preference of each operator. The cutting and polishing stones and wheels listed here are suitable for clinical occlusal recontouring.

1. Occlusal Contouring diamond instrument #8833,* maximal speed 120,000 R.P.M.
2. Football-Shaped Diamond number 8868-023,* maximal speed 80,000 R.P.M.
3. Dura-White stones, numbers 1C2, 1C4, FL1, and KN3.†
4. Enamel Adjustment Kit.†

The sequence of adjustments described here is based on the premise that it is desirable to develop maximal intercusping of the teeth in centric relation. The premolars and molars contact only in centric relation. The anterior teeth provide all eccentric closure contacts. These are basically the principal features of "organic occlusion" as described by Stuart and Stallard. It is unrealistic to expect routinely to develop three-point contact of each stamp cusp into its respective fossa by

*Brasseler U.S.A., Inc., Savannah, GA 31419.
†Shofu Dental Corporation, 4025 Bohannon Drive, Menlo Park, CA 94025.

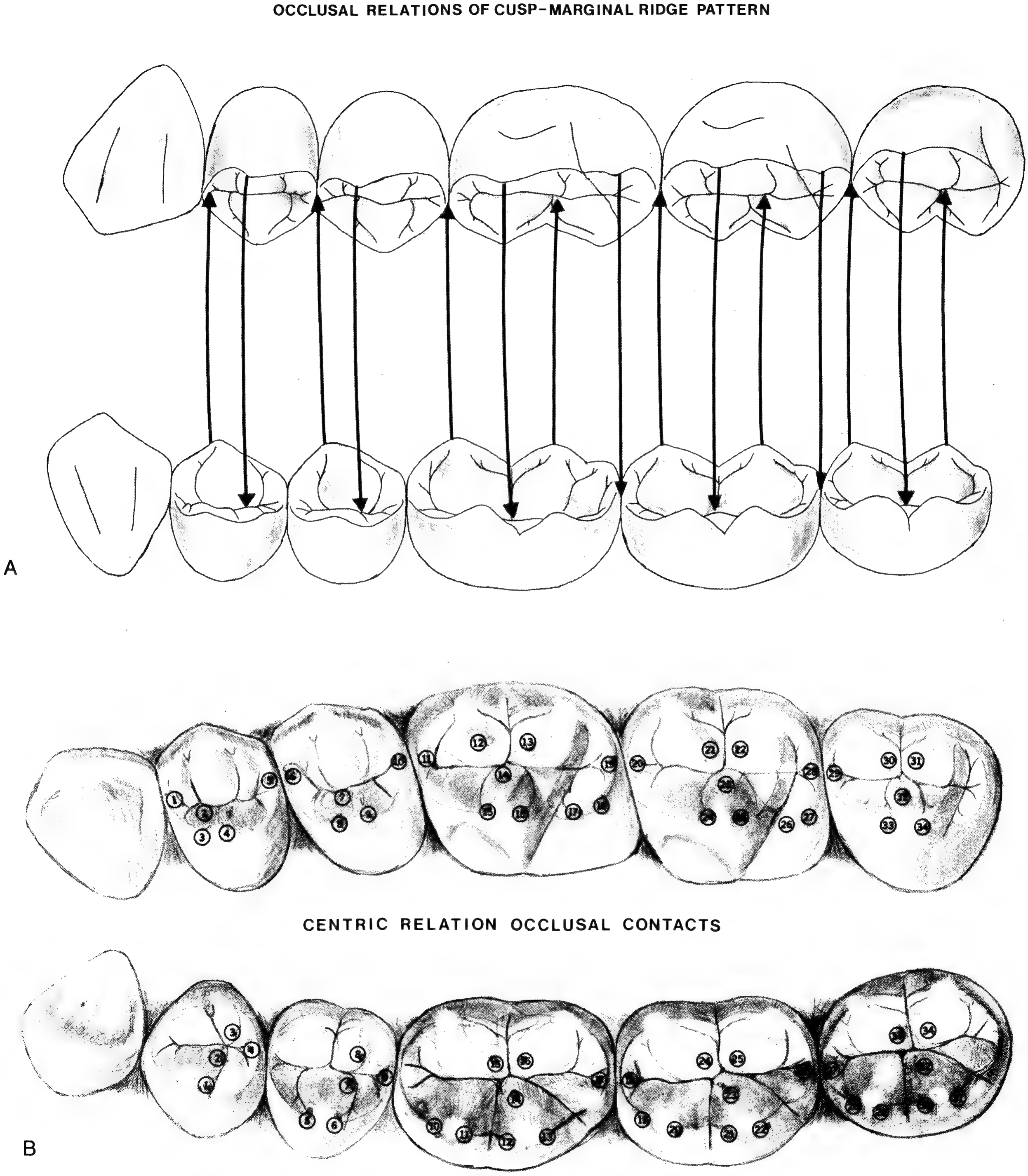


FIGURE 32–28 Cusp-Ridge Pattern of Occlusion

A, Relationships of opposing stamp cusps.
B, Points of occlusal contact.

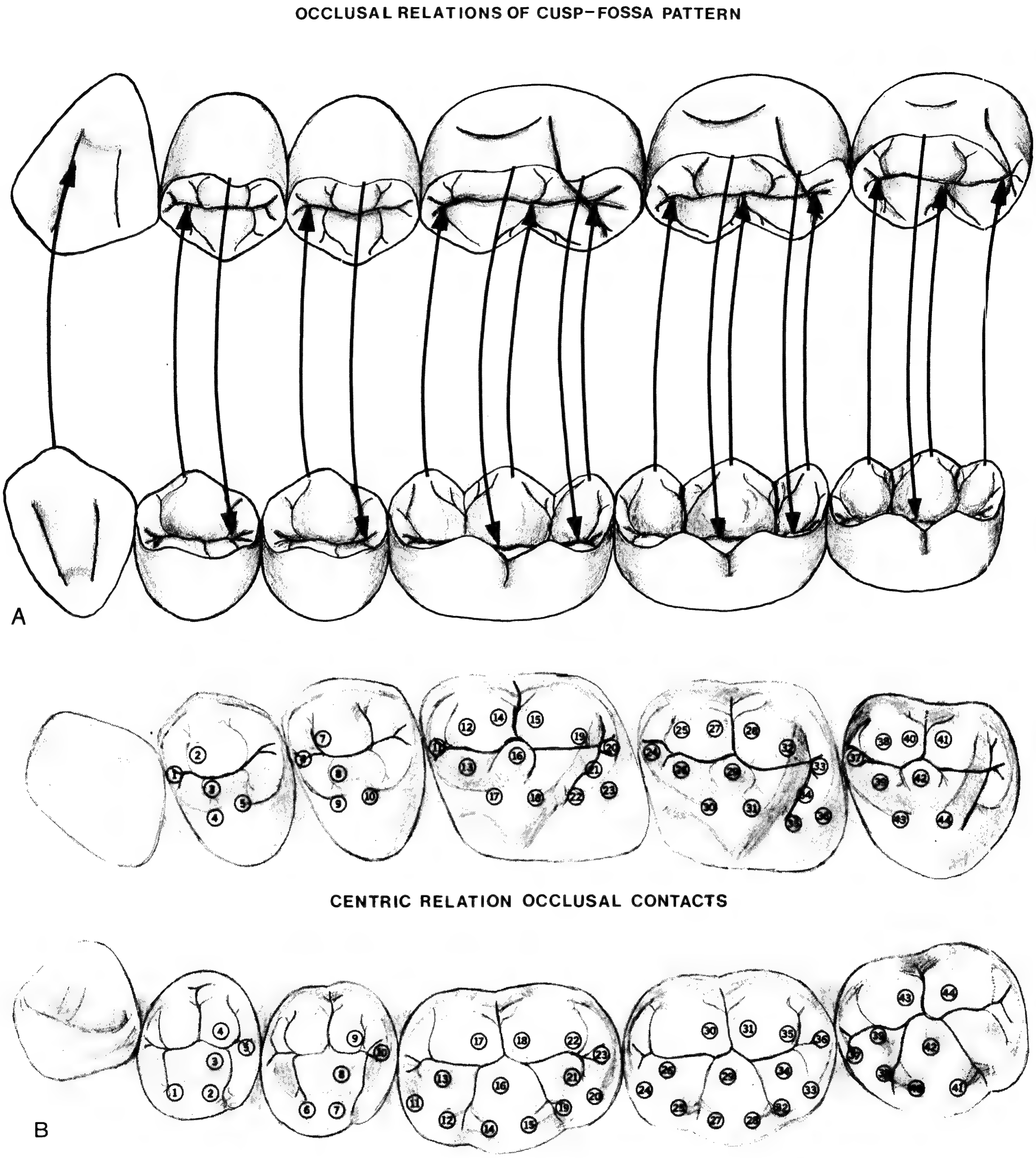


FIGURE 32–29 Cusp-Fossa Pattern of Occlusion

A, Relationships of opposing stamp cusps.
B, Points of occlusal contact.

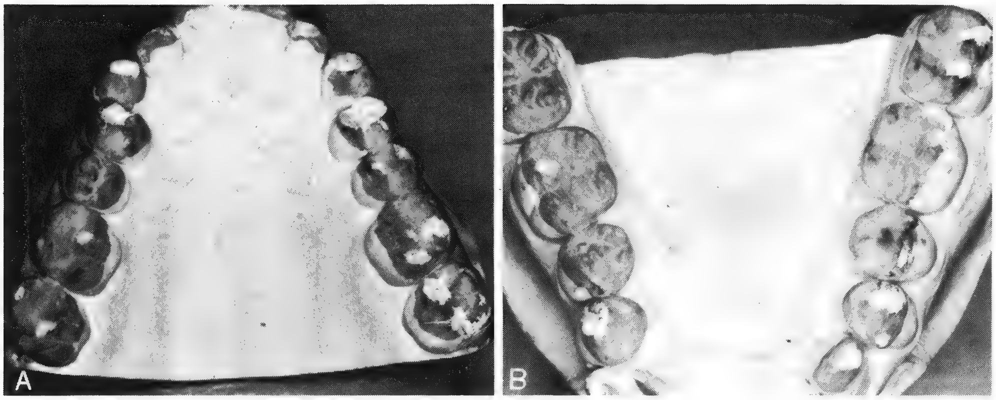


FIGURE 32–30
A, B, Maxillary and mandibular casts coated with poster paint. Equilibration has removed paint and produced a record of location and amount of change.

the grinding of tooth surfaces, since an increase in, as well as reduction of, the tooth's contour usually is needed to produce the tripodal effect of cusps fitting into fossae and for the development of the A, B, and C contacts shown in Figure 32–31.

Adjustments in the occlusion must be done by first consulting and correcting eccentric relations and then correcting the centric relation contacts. This is done for the same reasons that, during the development of occlusal surfaces in wax, the cusp positions and groove and ridge directions are arranged by first consulting eccentric movements. The centric relation contacts can then be completed with assurance that the resulting occlusal form will function eccentrically.

Correction of Protrusive Interferences

The teeth are moved into an end-to-end incisal relationship. If there is contact between premolars or molars, tooth structure is removed from the *facial* cusps of the *maxillary* teeth and the *lingual* cusps of the *mandibular* teeth until no contact remains. The removal of tooth structure is from the *distal* inclines of the *maxillary* teeth and the *mesial* inclines of the *mandibular* teeth (Fig. 32–32).

After removal of the interferences in the end-to-end relation, the mandible is moved distally toward centric relation. Contacts between premolars and molars are removed at each station along this distal mandibular movement. Contacts between premolars and molars at centric relation closure are maintained.

In the case of interference from a tipped mandibular molar, a groove is made in the distal marginal ridge of this molar to create a pathway for the lingual cusps of the maxillary molar.

Correction of Nonworking Interferences

The mandible is moved into an end-to-end relation of the canines on the working side. If contacts occur between opposing premolars or molars on the nonworking side, oblique grooves directed mesially are made in the maxillary teeth to serve as pathways for the mandibular facial cusps. Also, oblique grooves angled distally are made in the mandibular teeth to serve as pathways for the maxillary lingual cusps (Fig. 32–33).

Corrections of Working Interferences

The teeth are moved into the extreme lateral position to the extent of end-to-end relation of the canines on the working side. If there are interferences or simultaneous contact between premolars or molars on the working side, tooth structure is removed from the *facial* cusps of the *maxillary* teeth and the *lingual* cusps of the *mandibular* teeth. The reduction of tooth structure is from the *mesial* inclines of the *maxillary* teeth and the *distal* inclines of the *mandibular* teeth (Fig. 32–34).

Following the elimination of interference at end-to-end relations, the occlusion is tested slightly nearer centric relation. Successive stations are tested nearer and nearer to centric closure, and contacts of the posterior teeth are eliminated until centric relation is reached.

The procedure for correcting nonworking and working relations is repeated for the opposite lateral movement. An attempt is made to create approximately 1 mm of clearance between opposing posterior teeth in lateral end-to-end closure.

Testing of eccentric relations is facilitated by exerting slight pressure on the mandible toward the working side to assure maximal transtrusion (side shift).

Removal of interferences during the approach to centric relation closure from end-to-end lateral closure may require alternate correction on the working and on the nonworking sides as the contacts appear.

Correction of Centric Relation Occlusal Interferences

Centric relation occlusal contacts are corrected only after all eccentric interferences have been removed. The mandible is closed in centric relation until initial tooth contact is made. If increasing the closing force deflects

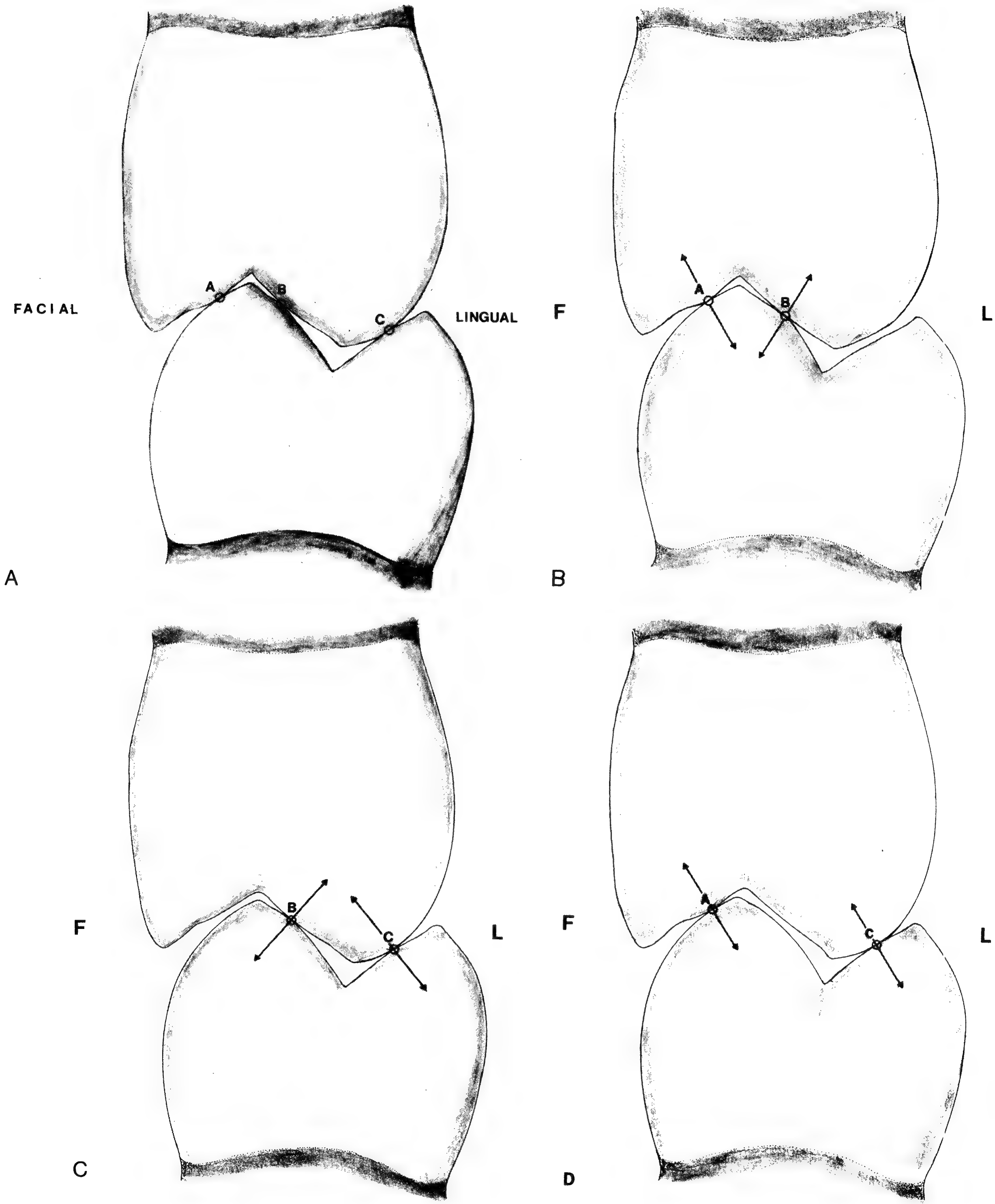


FIGURE 32–31
A, Ideal relationship of opposing posterior teeth in which A, B, and C contacts have been achieved.
B, C, D, Situations in which only two of the three contacts have been obtained. Note that in B and C the force vectors are offsetting and promote stability, whereas in D they are parallel and may tend to adversely reposition the teeth.

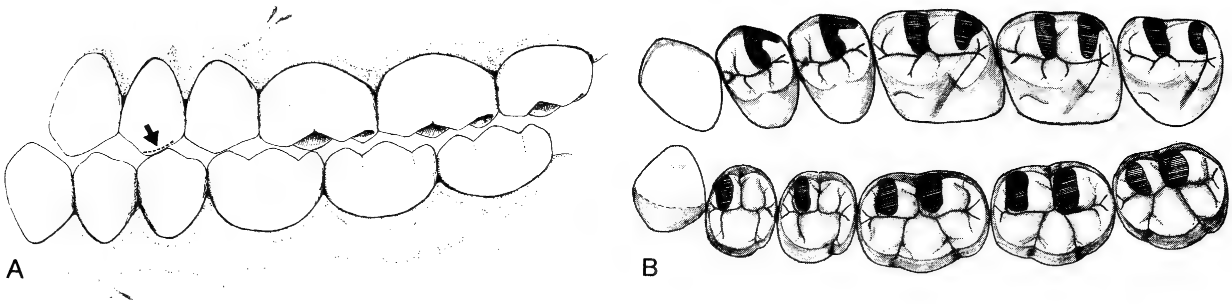


FIGURE 32–32 Interferences During Protrusive Movement

A, The arrow indicates interference on the distal incline of the facial cusp of the maxillary first premolar.
B, Protrusive interferences are eliminated by reducing distal inclines of maxillary facial cusps and mesial inclines of mandibular lingual cusps.

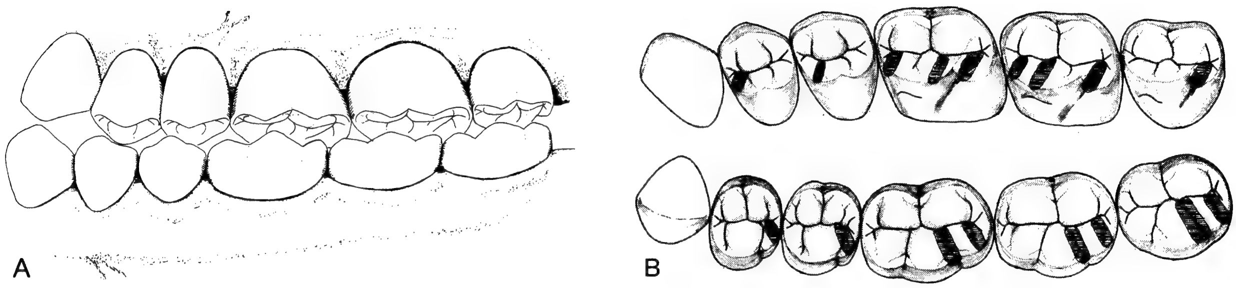


FIGURE 32–33 Interferences on the Nonworking Side

A, Left facial view showing posterior nonworking interferences on second premolar and molars.
B, The areas that may need to be equilibrated. Grooves are accentuated or created with mesial inclination on maxillary teeth and distal inclination on mandibular teeth.

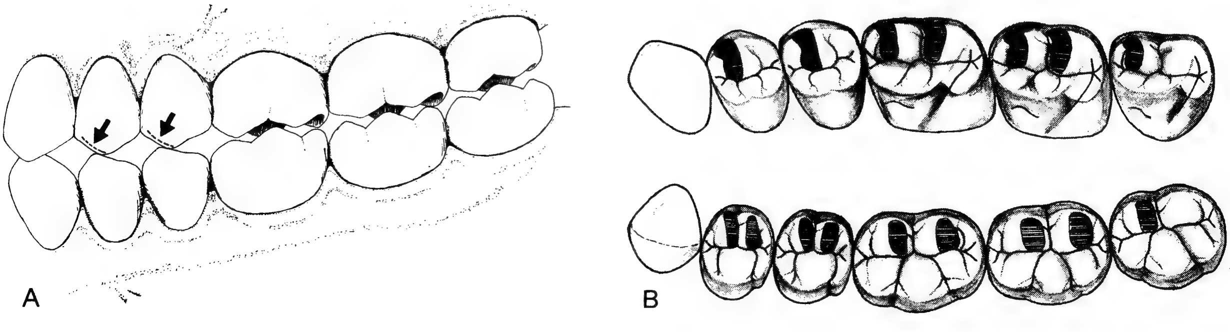


FIGURE 32–34 Interferences on the Working Side

A, Left working movement. Arrows indicate interferences on mesial inclines of maxillary premolars.
B, The areas that may need to be reduced to eliminate working interferences are the mesial inclines of maxillary facial cusps and the distal inclines of mandibular lingual cusps.

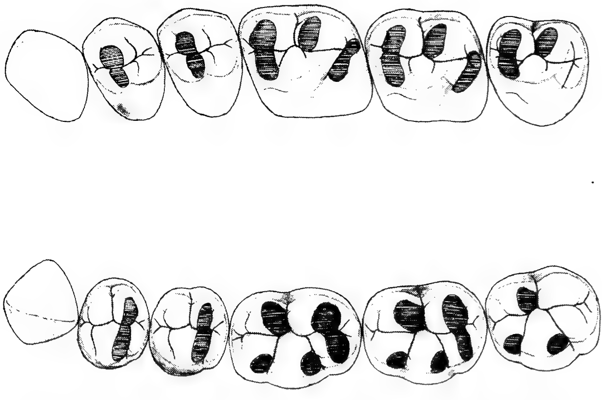


FIGURE 32–35 Areas that may need to be reduced to eliminate centric occlusal interferences.

the mandible to a more closed position, corrections must be made. The paths of the rubbing inclines are marked with articulating paper, and reductions are made on the mesial slopes of the maxillary teeth and the distal slopes of the mandibular teeth (Fig. 32–35). Sufficient reduction is made to eliminate the "slide." The final step is to deepen the fossae to establish a centric-related closure equal to, or more closed than, the dimension of the former eccentric maximal closure.

The goal of occlusal adjustment is to create a stable closure and simultaneous contact of all teeth in centric relation. All eccentric closure contacts are to be between anterior teeth, and centric-related intercusping becomes the most closed tooth-supported closure.

WAX BUILDUP OF ORGANIC OCCLUSION

Dr. Everett Payne is credited for developing a method of waxing that truly integrates occlusal components, in both centric occlusion and eccentric relationships. Called the "add on," "wax added," or "wax-to-wax" technique, it is being used successfully by many dental schools in the teaching of functional occlusal morphology.* It is in widespread use, usually in modified form, for the evolution of functional occlusion in oral rehabilitative operations when all posterior occlusal surfaces are rebuilt simultaneously. Originally, Payne's technique brought about what is basically a cusp-ridge relationship. The gnathologic approach to oral rehabilitation that produces a cusp-fossa arrangement of the teeth customarily employs a modification of Dr. Payne's waxing procedures. Very often existing tooth orientation does not permit the ideal cusp arrangement for either of these approaches, and alterations must be practiced to obtain a workable occlusion if the teeth are not to be rearranged orthodontically.

The knowledge and skill gained by mastering this method of waxing may be beneficial in numerous ways even if it is never used in advanced oral rehabilitation. As a diagnostic procedure, this system may be utilized for prewaxing a case before final determination of treatment. The method may be used in its entirety at any time that opposing posterior surfaces are to be restored with castings. Also, many of the steps in the procedure may be employed to refine the occlusal morphology of wax patterns although the location, height, and basic form of the components may be decided in advance by an existing opposing surface that is not to be altered. Learning this operation increases appreciation for the functional aspects of occlusal morphology and thereby helps to improve the ability to attain a benign occlusion regardless of the restorative material being placed or the extent of the restoration being made.

The waxing process for developing a cusp-ridge occlusal pattern for cast dental restoration is presented in Chapter 13; therefore, only cusp-fossa waxing is described here.

Drs. P. K. Thomas* and C. E. Stuart† are credited for developing the procedures for waxing of an organic occlusion by altering Payne's method to produce a cusp-fossa arrangement.

The first step in waxing of clinical restorations is to form the missing axial contours of all *teeth* to be rebuilt. This is done on dies, and the patterns are transferred to the articulated working casts. At this time the occlusal surfaces are relatively flat, and there must be adequate occlusal space to allow development of the components of the occlusal surface. For instructional purposes, the waxing exercise described here is demonstrated on casts from which the occlusal surfaces have been trimmed to simulate a clinical situation (Fig. 32–36).

Dr. Peter K. Thomas has designed a set of five instruments that are very helpful in waxing the occlusal elements of teeth to be restored (Fig. 32–37). Numbers 1 and 2 PKT waxing instruments are used to add wax. Numbers 3, 4, and 5 PKT instruments are used to carve and shape the ridges and grooves.

The order in which the basic occlusal components are added in wax is as follows:

1. Wax cones formed to establish location and heights of cusps
   a. Maxillary facial cusp tips
   b. Maxillary lingual cusp tips
   c. Mandibular facial cusp tips
   d. Mandibular lingual cusp tips
2. Marginal and cusp ridges
3. Completed axial contours
4. Triangular and oblique ridges
5. Developmental and supplemental grooves
6. Centric relation occlusal contacts

ESTABLISHING MAXILLARY FACIAL CONES

The maxillary facial cusp cones are first established for the first premolar, then for the second premolar,

*Wilson, H and Lang, R: Practical Crown and Bridge Prosthodontics. New York, McGraw-Hill Company, Inc., 1962.

*Thomas, P: Syllabus on full mouth waxing technique for rehabilitation tooth-to-tooth cusp-fossa concept of organic occlusion, San Francisco, CA, University of California Press, 1967.

†Stuart, C: Syllabus on full mouth waxing technique for rehabilitation tooth-to-tooth cusp-fossa concept of organic occlusion, San Francisco, CA, University of California Press, 1980.

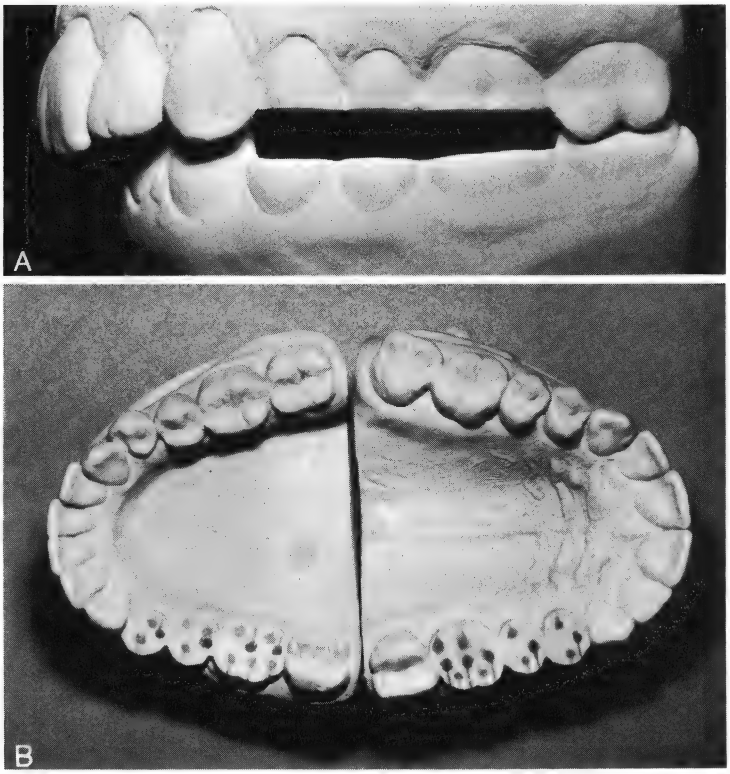


FIGURE 32–36 Casts for Waxing Cusp-Fossa Occlusion

A, Vertical space available for waxing.
B, Occlusal view showing position of cones. Darker central dots represent the positions of fossae that will receive opposing stamp cusps. Light dots locate cusp tips.

followed by the first molar and on through the last molar (Fig. 32–38). Positions for these cusp tips are chosen to provide the proper horizontal overlap with the mandibular teeth and a mesiodistal relationship that allows the maxillary facial cusps to pass distally to the mandibular facial cusps as the mandible enters or leaves centric-related closure. Adequate clearance for developing the triangular, marginal, and cusp ridges must be provided. The lengths of the cones are adjusted to develop the proposed occlusal plane and the anteroposterior occlusal curve. Evaluation of the relationships of the cones should be made by moving the articulator into lateral, lateroprotrusive, and protrusive movements.

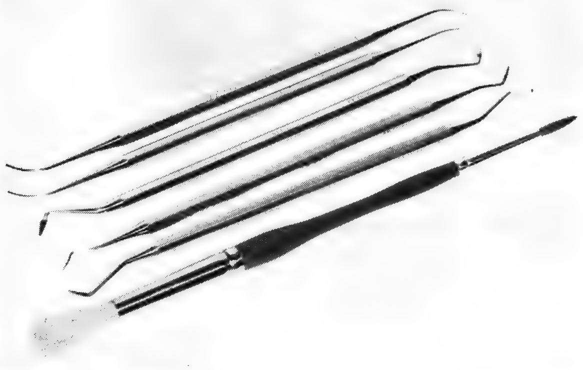


FIGURE 32–37 Waxing instruments. From top to bottom: PKT numbers 1, 2, 3, 4, and 5; Whip-Mix plate brush.

Establishing Maxillary Lingual Cones

As with the facial cones, the lingual cusp cones are formed one at a time in a sequential order. The lingual cusp tips of the premolars are positioned so that they center in the projected distal fossae of the mandibular premolars (Fig. 32–39). The lengths of the premolar lingual cones are made to be approximately the same as the lengths of the facial cones. The cusp cones should not contact the opposing teeth, since space must remain for formation of ridges and fossae in these teeth. This consideration must be made in positioning of all cusps into fossae.

The mesiolingual cusp tip of the maxillary first molar is positioned to seat in the central fossa of the mandibular first molar. The distolingual cusp cone projects into the distal fossa of the mandibular first molar. When both molar teeth are viewed facially, the mesiolingual cusp tips are positioned between the facial cones and are slightly longer than the facial cusp tips (Fig. 32–39*A*). As the mandible moves in and out of centric relation, the maxillary molar mesiolingual cusps pass over the developmental grooves between the distofacial and distal cusps of the mandibular molar on the orbiting side. The distolingual cusp points pass distally to the projected distolingual cusp of the mandibular molar on the rotating side and mesially to the mesiobuccal cusp of the next mandibular molar. The distolingual cusp tips are slightly shorter than the mesiolingual cusps,

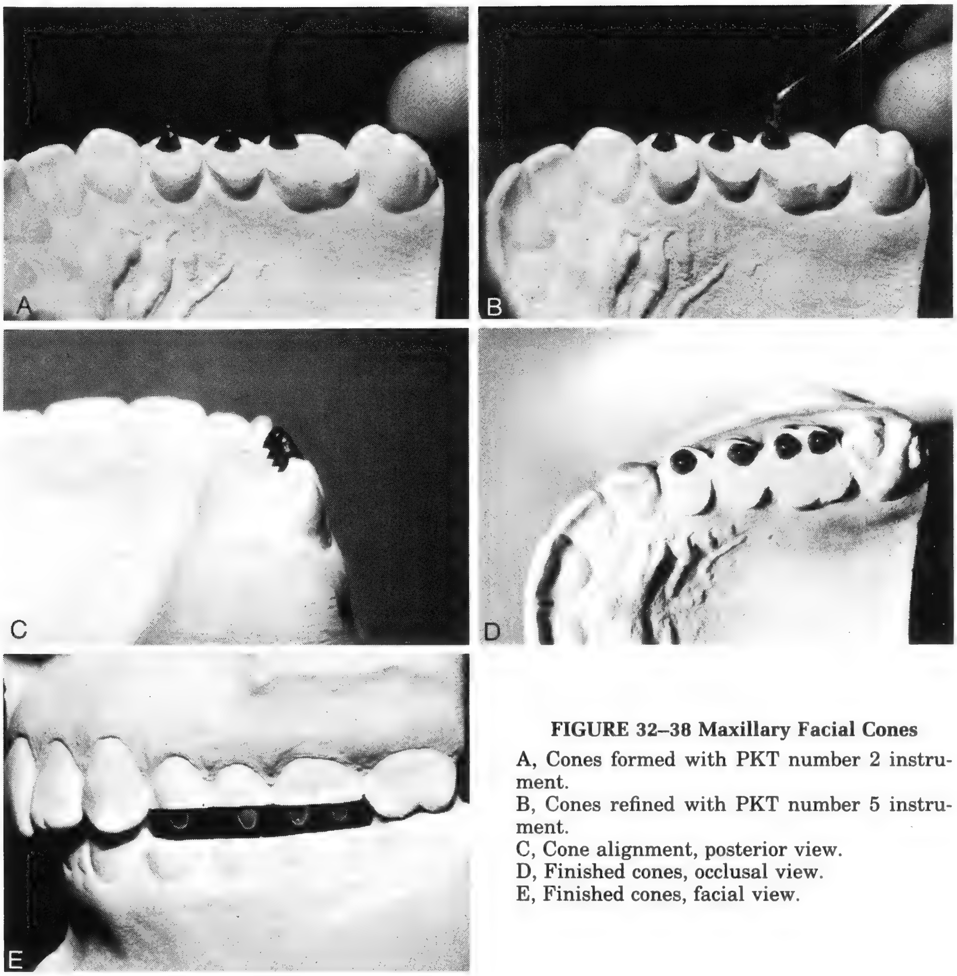


FIGURE 32–38 Maxillary Facial Cones

A, Cones formed with PKT number 2 instrument.
B, Cones refined with PKT number 5 instrument.
C, Cone alignment, posterior view.
D, Finished cones, occlusal view.
E, Finished cones, facial view.

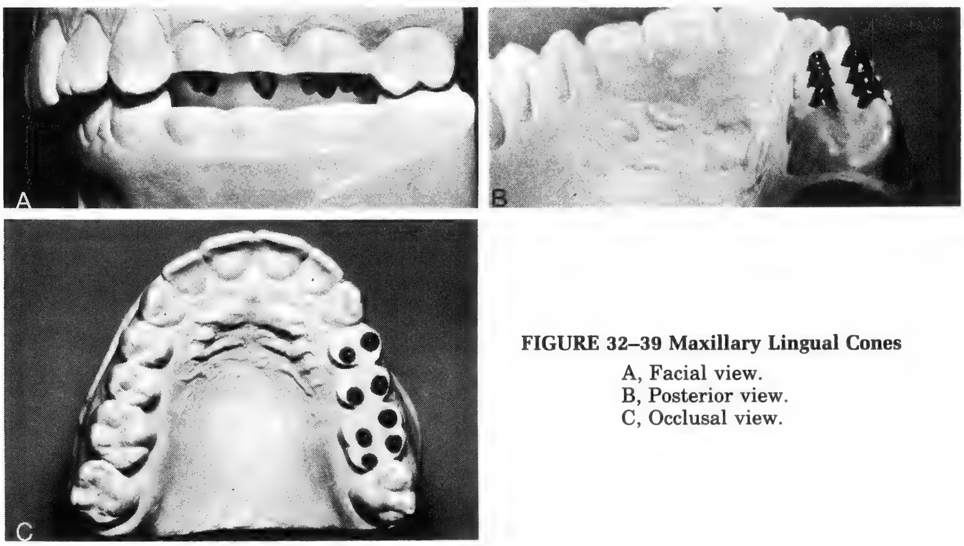


FIGURE 32–39 Maxillary Lingual Cones

A, Facial view.
B, Posterior view.
C, Occlusal view.

and both should clear in all eccentric movements of the mandible.

ESTABLISHING MANDIBULAR FACIAL CONES

The facial cusp cone of the first premolar is positioned beneath the projected mesial fossa of the maxillary first premolar (Fig. 32–40). There should be no contact with the maxillary facial cusp cones as the mandibular premolar passes mesially in working relations. The facial cusp cone for the mandibular second premolar is formed in a similar manner.

The mesiofacial cusp cone of the mandibular first molar is formed to seat in the mesial fossa of the maxillary first molar. This cusp tip should pass mesially to the mesiofacial cusp of the maxillary first molar during working movement. The distofacial cusp is then formed to seat in the central fossa of the maxillary first molar and is positioned to allow the mesiofacial cusp of the maxillary first molar to pass mesially to it and distally to the mandibular mesiofacial cusp during a working movement. Next, the distal cusp cone is positioned to seat in the distal fossa of the maxillary first molar. In a working movement, the distal cusp passes distally to the distofacial cusp of the maxillary molar. In a nonworking movement, this cusp passes distally to the mesiolingual cusp of the maxillary molar. During protrusive and lateroprotrusive closures, the anterior teeth disallow any contacting of the maxillary and mandibular cusp tips. The facial cusp cones of the mandibular second molar are formed by using the same criteria.

ESTABLISHING MANDIBULAR LINGUAL CONES

The mandibular first premolar lingual cone represents a shearing cusp that does not seat into a fossa. The height should be considerably shorter than the facial cusp height (Fig. 32–41). In working relations, this cusp passes mesially to the lingual cusp tip of the maxillary first premolar.

Two lingual cusp cones are formed on the second premolar, both of which are higher than the lingual cone on the first premolar; however, they should be shorter than the facial cone. In working relations, these lingual cusp cones pass beneath, or mesially to, the maxillary lingual cusp tip.

The mesiolingual cusp cone of the mandibular first molar is positioned so that the mesiolingual cusp tip of the maxillary first molar passes distally to it in working relation, and the distolingual cusp point is positioned so that the maxillary mesiolingual cusp passes mesially to it. The cusp lengths are established so there is ample clearance in all eccentric movements. The lingual cusp cones of the mandibular second molar are developed in a similar manner.

FIGURE 32–40 Mandibular facial cones formed. Cones are positioned to pass anteriorly to the maxillary facial cones during working movement.

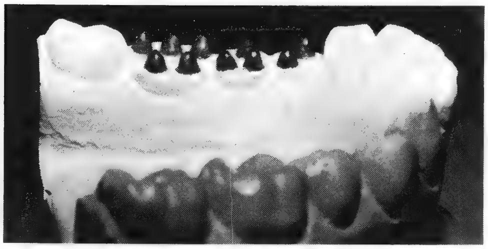


FIGURE 32–41 Mandibular lingual cones formed.

At this point, all cusp cones should be examined, and any changes should be made to assure that proper anteroposterior and faciolingual occlusal curves have been established. There should be a minimal clearance of 1 mm in all eccentric movements.

ESTABLISHING MARGINAL AND CUSP RIDGES

Maxillary Teeth

First, the mesial marginal and cusp ridges of the maxillary first premolar are formed by flowing wax from the facial cusp tip forward following the mesial contour of the projected occlusal surface around to the lingual cusp tip. Next, the distal marginal ridge is similarly formed to complete the outline of the occlusal surface. This procedure is repeated to form the ridges of the second premolar and the molars. The completed ridges should be examined to assure that the cusp tips are the highest points (Fig. 32–42).

Mandibular Teeth

The mandibular marginal and cusp ridges are formed in the same manner as for the maxillary teeth (Fig. 32–42). Since these ridges form centric occlusal contacts with the maxillary ridges, each addition of wax must be followed by closure of the articulator before the wax hardens to prevent excess wax buildup or fracture of the patterns. This is true of all the remaining steps as well.

Centric Occlusal Contacts

The centric occlusal contacts on marginal ridges and cusp ridges and facial and lingual contours on premolar and molar teeth are as follows:

Mandibular First Premolar

1. Contact occurs between the mesial slope of the facial cusp ridge and the mesial marginal ridge of the maxillary first premolar.
2. Contact occurs between the distal marginal ridge of the mandibular first premolar and the distal cusp ridge of the lingual cusp of the maxillary first premolar.

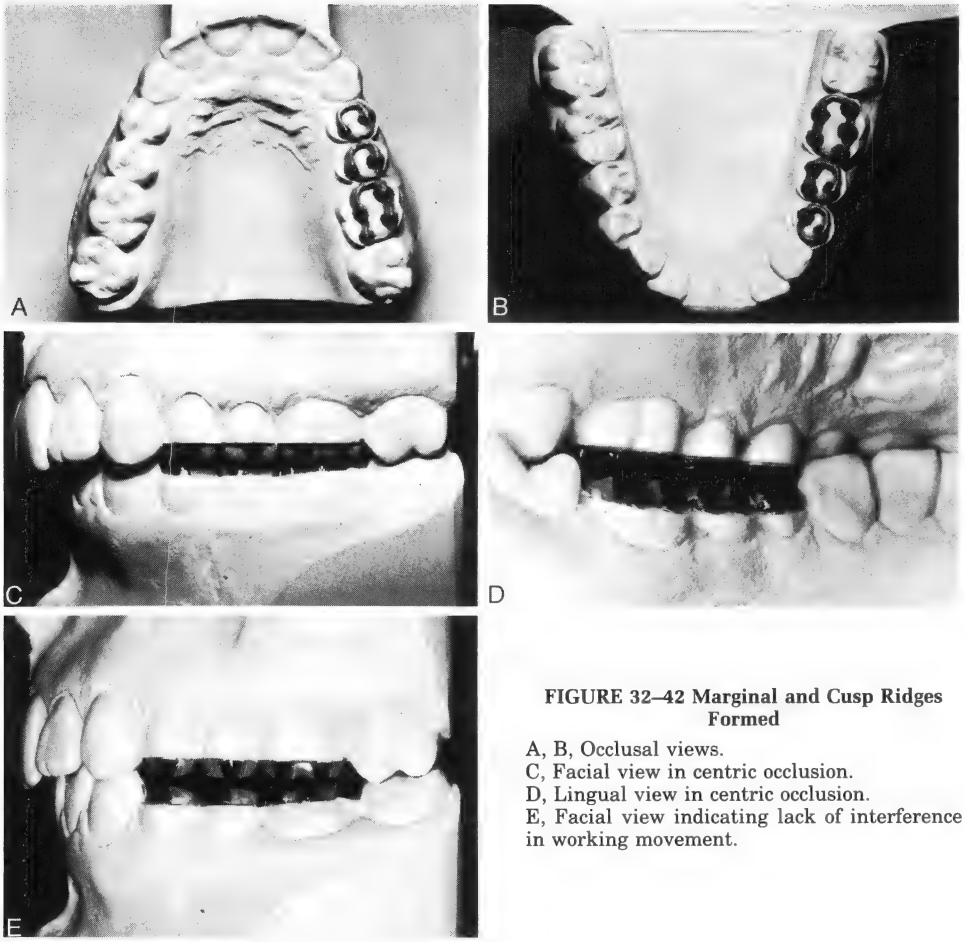


FIGURE 32–42 Marginal and Cusp Ridges Formed

A, B, Occlusal views.
C, Facial view in centric occlusion.
D, Lingual view in centric occlusion.
E, Facial view indicating lack of interference in working movement.

Mandibular Second Premolar

Contact is the same as for the first premolar.

Mandibular First Molar

1. Contact occurs between the mesial marginal ridge of the mesiofacial cusp and the mesial marginal ridge of the maxillary first molar.
2. Contact occurs between the distal marginal ridge and the distal slope of the distolingual cusp of the maxillary first molar.

Mandibular Second and Third Molars

Contact is the same as for the first molar.

Axial Contours Completed

The facial and lingual contours are completed by applying wax between the marginal and cusp ridges and the axial contour (Fig. 32–43).

Establishing Triangular Ridges

Maxillary Teeth

The triangular ridge of the maxillary first premolar is formed by placing a ridge of wax from the facial cusp tip toward the area of the projected central developmental groove (Fig. 32–44*A*). This ridge is narrow at the cusp tip and becomes wider as it approaches the central groove. The lingual triangular ridge is formed next in the same manner so that it joins the facial triangular ridge at the central developmental groove. The first centric occlusal contact on a triangular ridge is created by contact between the distal slope of the facial cusp ridge of the mandibular premolar and the facial triangular ridge of the maxillary premolar. The procedure is repeated for the second premolar with a similar contact resulting.

The mesiofacial triangular ridge of the maxillary first molar is formed by applying wax between the mesiofacial cusp tip and the projected location of the central fossa. The triangular ridge of the mesiolingual cusp is next formed and directed toward the central fossa. Then the oblique ridge from the distofacial cusp is directed toward the mesiolingual cusp. This ridge dips cervically as the area of the central groove is approached, and after crossing this groove it is directed toward the mesiolingual cusp to form the oblique ridge. The last triangular ridge is formed by placing a small ridge of wax from the distolingual cusp toward, and at a right angle to, the oblique ridge. The triangular and oblique ridges of the second molar are formed in a similar manner.

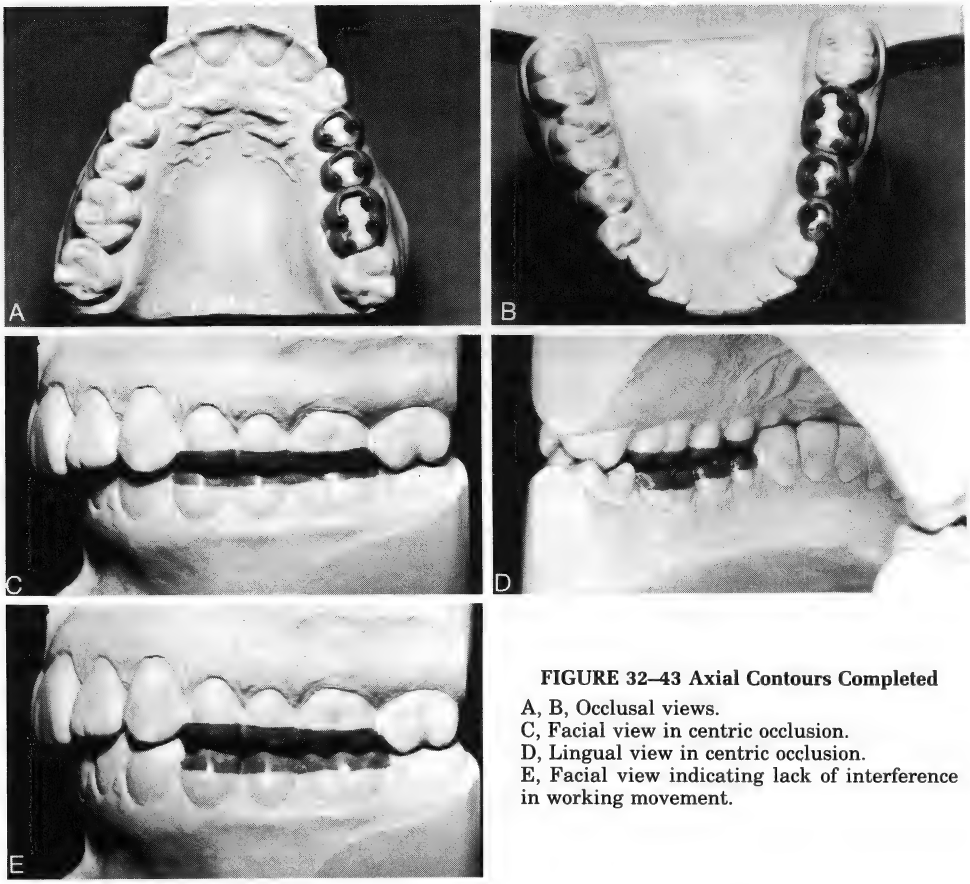


FIGURE 32–43 Axial Contours Completed

A, B, Occlusal views.
C, Facial view in centric occlusion.
D, Lingual view in centric occlusion.
E, Facial view indicating lack of interference in working movement.

Mandibular Teeth

The mandibular premolar triangular ridges are formed to extend from the facial and lingual cusp tips toward the central groove. The facial and lingual triangular ridges of the mandibular first molar are likewise directed from the cusp tips toward the central fossa (Fig. 32–44*B*). The procedure is repeated for the second and third molars.

Centric Occlusal Contacts

The centric occlusal contacts of the triangular ridges on premolar and molar teeth are as follows:

First Premolars

1. The mesial slope of the facial triangular ridge of the maxillary first premolar crosses and contacts the

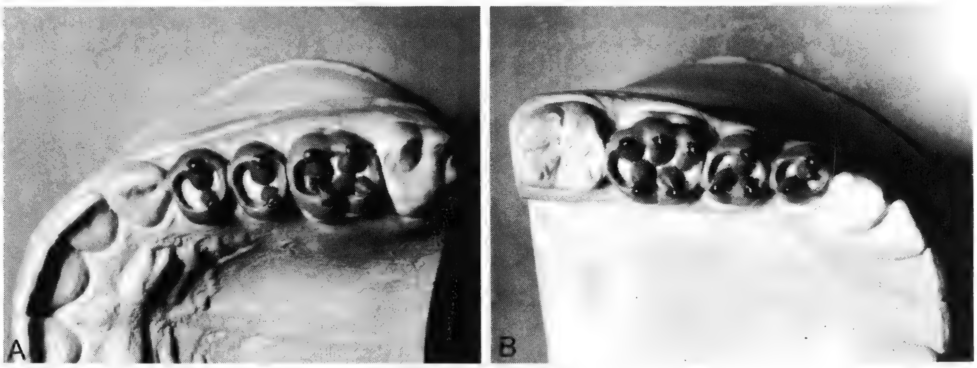


FIGURE 32–44 Triangular Ridges Formed

A, Maxillary arch.
B, Mandibular arch.

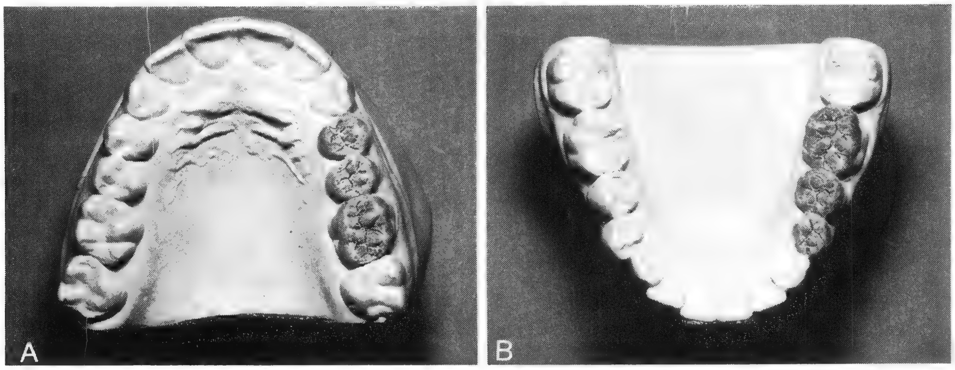


FIGURE 32–45
A, B, Occlusal view of finished waxing showing developmental and supplemental grooves.

distal slope of the facial cusp ridge of the mandibular first premolar. (See premolar contact number 2, Fig. 32–47.)

2. The mesial slope of the lingual triangular ridge of the maxillary first premolar contacts the distal slope of the facial triangular ridge of the mandibular first premolar. (See premolar contact number 3, Fig. 32–47.)
3. The distal slope of the lingual triangular ridge of the mandibular first premolar contacts the mesial slope of the lingual surface of the lingual cusp of the maxillary first premolar. (See premolar contact number 4, Fig. 32–47.)

Second Premolar

The centric occlusal contacts are the same as for the first premolar.

First Molar

1. The mesial slope of the maxillary mesiofacial triangular ridge crosses and contacts the distal slope of the facial cusp ridge of the mesiofacial cusp of the mandibular first molar. (See molar contact number 2, Fig. 32–47.) The distal slope of the maxillary mesiofacial triangular ridge crosses and contacts the mesial slope of the facial cusp ridge of the distofacial cusp of the mandibular first molar. (See molar contact number 4, Fig. 32–47.)
2. The mesial slope of the maxillary distofacial triangular ridge crosses and contacts the distal slope of the facial cusp ridge of the distofacial cusp of the mandibular first molar. (See molar contact number 5, Fig. 32–47.) The distal slope of the maxillary distofacial triangular ridge crosses and contacts the mesial slope of the facial cusp ridge of the distal cusp of the mandibular first molar. (See molar contact number 7, Fig. 32–47.)
3. The distal slope of the mesiofacial triangular ridge of the mandibular first molar contacts the mesial slope of the mesiolingual supplemental ridge of the maxillary first molar. (See molar contact number 3, Fig. 32–47.)
4. The distal slope of the distofacial triangular ridge of the mandibular first molar contacts the mesial slope of the mesiolingual triangular ridge of the maxillary first molar. (See molar contact number 6, Fig. 32–47.)
5. The distal slope of the triangular ridge of the distofacial cusp of the mandibular first molar contacts the mesial slope of the distolingual triangular ridge of the maxillary first molar. (See molar contact number 9, Fig. 32–47.)
6. The distal slope of the mesiolingual triangular ridge of the mandibular first molar contacts the mesial slope of the lingual surface of the mesiolingual cusp of the maxillary first molar. (See molar contact number 10, Fig. 32–47.)
7. The mesial slope of the distolingual triangular ridge of the mandibular first molar contacts the distal slope of the lingual surface of the mesiolingual cusp of the maxillary first molar. (See molar contact number 11, Fig. 32–47.)
8. The distal slope of the triangular ridge of the disto-

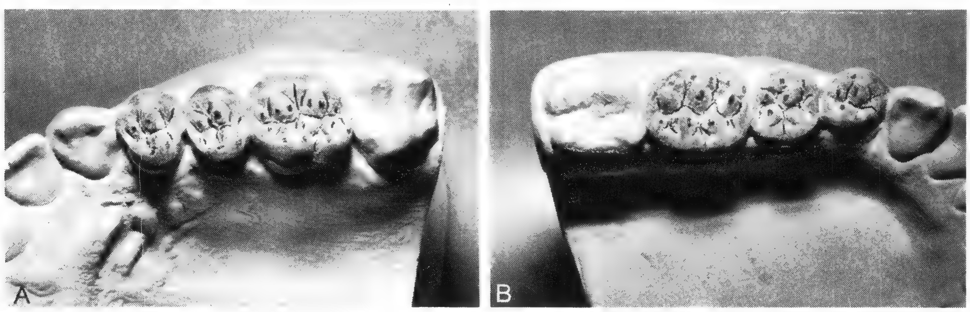


FIGURE 32–46
A, B, Centric relation occlusal contacts refined.

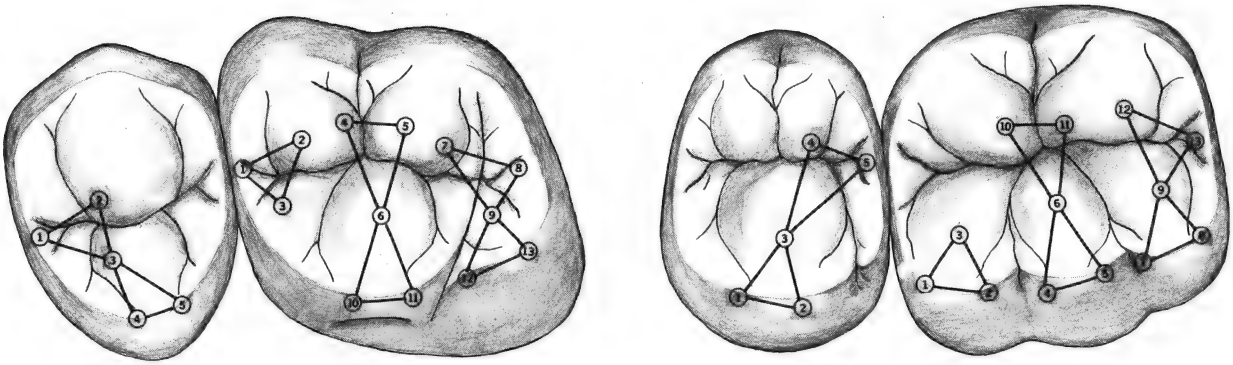


FIGURE 32–47 Tripodal occlusal contacts.

lingual cusp of the mandibular first molar contacts the mesial slope of the lingual surface of the distolingual cusp of the maxillary first molar. (See molar contact number 12, Fig. 32–47.)

Second Molar and Third Molar

The centric occlusal contacts are the same as for the first molar except that often there are situations in

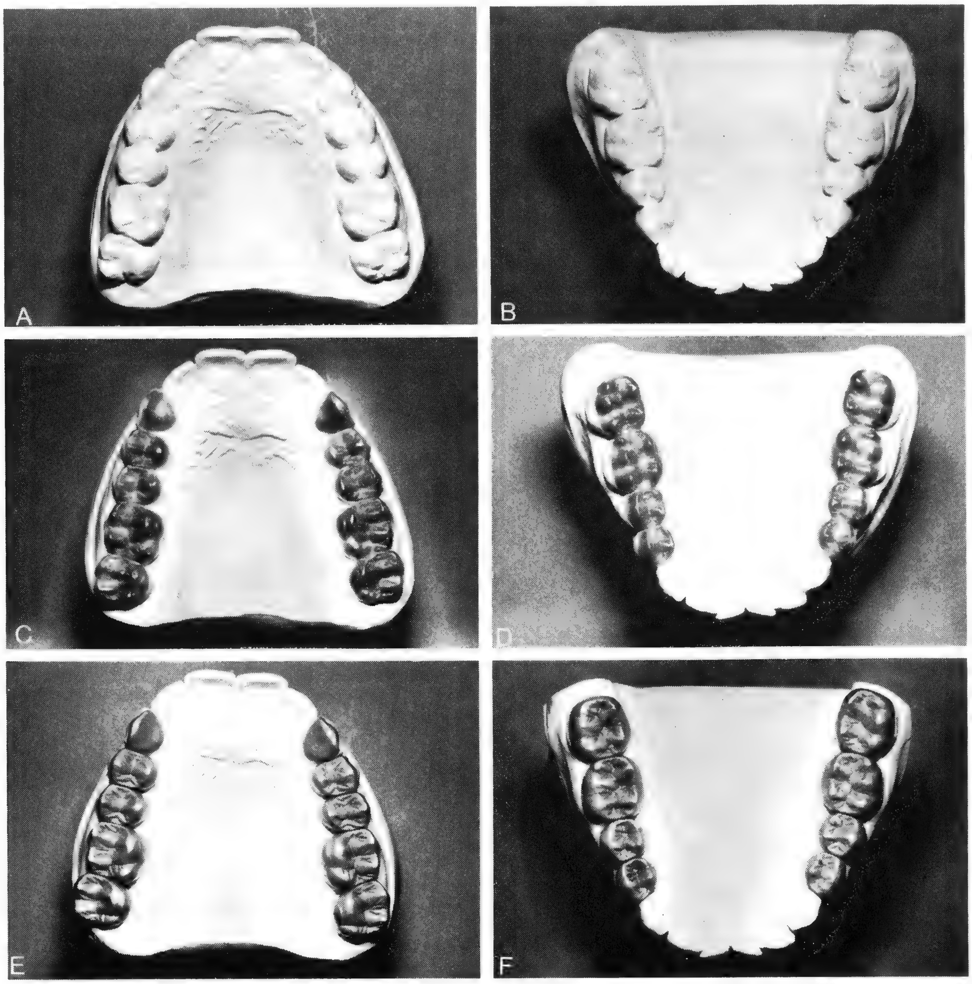


FIGURE 32–48 Completed Restorations

A, B, Diagnostic casts.
C, D, Wax patterns, occlusal view.
E, F, Completed castings, occlusal view.

which contact cannot be established between the distal cusp of the mandibular third molar and the distal fossa of the maxillary third molar.

Establishing Developmental and Supplemental Grooves

The areas between the ridges are filled with wax, and the articulator is closed with each application. Any excess wax is removed during completion of the sharp-bottomed V-shaped developmental grooves with the number 4 PKT carving instrument. In the finished waxing, the stamp cusps seat over developmental grooves and have centric occlusal contacts on the ridges.

Supplemental grooves are located around each triangular ridge. They are carved to follow the outline of the triangular ridge and serve to sharpen the ridge. Producing the supplemental grooves also serves to form the supplemental ridges. In contrast to the relatively sharp-bottomed V-shaped developmental grooves, the supplemental grooves are shallower and more U-shaped in cross section (Fig. 32–45).

Refining Centric Occlusal Contacts

If the proper sequence of developing each occlusal element is followed, the finished occlusal contours should emerge with stamp cusps seating in three-point contact in their respective fossae and developmental and supplemental grooves in position to serve as passageways for these cusps as they enter and leave centrically related contacts (Fig. 32–46). The tripodal effect of the three-point contact of stamp cusps seating in fossae is shown in Figure 32–47.

Completed Restorations

The procedures for developing cast restorations in an oral rehabilitative operation when all posterior occlusal surfaces are rebuilt simultaneously is illustrated in Figure 32–48. The development of a cusp-fossa pattern of occlusion in restorations is accomplished only after an analysis of the occlusal relations that are observed on the mounted diagnostic casts, adjustment of the occlusal interferences on the mounted casts, prewaxing of the occlusal surfaces to be restored, and, finally, waxing the desired morphology on casts.

A FINAL NOTE

The objective of this chapter was to present information related to dental occlusion that is not discussed in earlier chapters—information that is decidedly important to the practice of fixed prosthodontics. The scope of this subject deserves much broader coverage, and readers are encouraged to refer to other books and publications to obtain a more comprehensive view.

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